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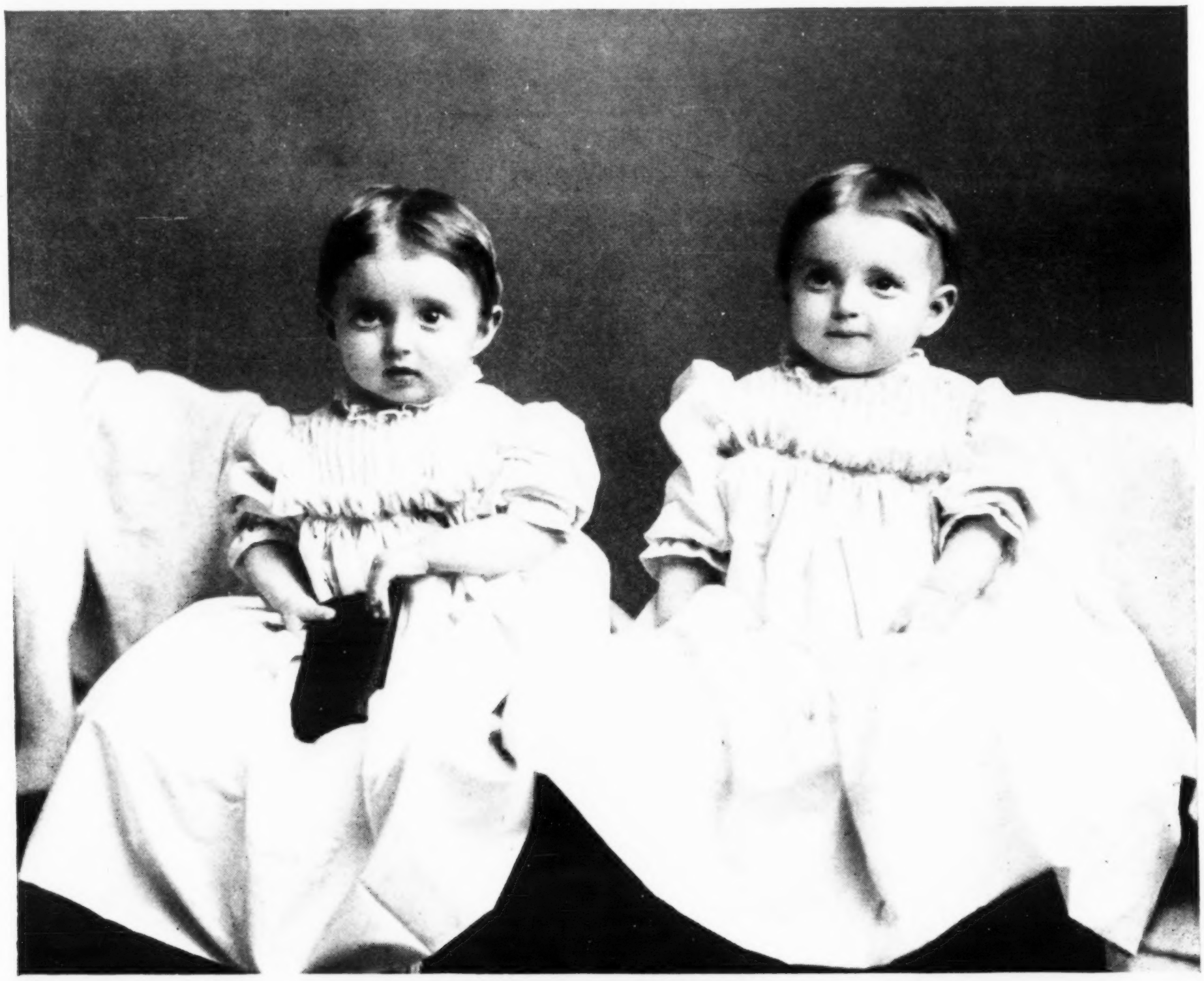

MABEL AND MARY AS BABIES

Reared apart since babyhood, their test-differences today are greater than those of any pair of identical twins so far tested.

(SEE PAGE 3)

Sex-Chimeras in Wasps

Science in Human Affairs

Pink Lemons

Breeding Chinchilla Rabbits

VOLUME 23 JANUARY, 1932 NUMBER 1

The American Genetic Association

An incorporated organization devoted to promoting a knowledge of the laws of heredity and their application to the improvement of plants, animals, and human racial stocks

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IN THIS ISSUE

MENTAL AND PHYSICAL TRAITS OF IDENTICAL TWINS REARED APART
By H. H. Newman 3

THE OPPORTUNITY OF SCIENCE 19

A PINK-FRUITED LEMON
By A. D. Shamel 23

FERTILE GYNANDROMORPHS IN HABROBRACON
By P. W. Whiting and E. J. Wenstrup 31

HEREDITARY VARIATION OF THE CHINCHILLA RABBIT
By Paul B. Sawin 39

BOOKS RECEIVED 27

THE SCIENCE OF HUMAN AFFAIRS THE MOST DIFFICULT 22

IS EDUCATION IMPROVING? (REV.) 28

INSPIRATIONAL HEREDITY (REV.) 29

HEREDITY AND DIABETES 30

A GLOSSARY OF GENETIC TERMS ..... *Third Cover*

COMING

The New England Puritans
An Obituary

Is Family-Size Hereditary?
Statistical evidence on whether family-size tends to run in families.

Twisted Tree Trunks
Often alleged to be due to wind or other environmental stimuli, is not this peculiarity inherited?

I Q Differences of Twins Reared Together
Four instances of rather marked I. Q. differences in identical twins that have been reared in the same environment.

"Tasters" and "Non-Tasters"
Inherited differences in taste reactions to Phenyl Thio Carbamide and other substances.

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ARE THEIR TEST-DIFFERENCES DUE TO ENVIRONMENT?

Frontispiece

Living in the same state, less than a hundred miles apart, Mary (left) grew up in a small town, and Mabel on a farm. They differ more in test reactions mentally, temperamentally and physically than any of the other twin pairs studied up to this time. This in spite of the fact that in this case the environmental factors are apparently less different than in at least three of the cases studied. When the picture was taken the twins were seventeen, at which time they still looked very much alike. At the present time Mabel weighs 27 pounds more than Mary and their similarity is not so striking.

MENTAL AND PHYSICAL TRAITS OF IDENTICAL TWINS REARED APART

Case IV. *Twins Mary and Mabel, and Review of the First Four Cases Studied*

H. H. Newman
University of Chicago

IT has been nearly three years since the three earlier cases ("A" and "O", "E" and "G", and "C" and "O") were studied. These earlier cases came to my attention almost simultaneously, and there was some reason, at that time, to expect to discover and to study at least ten cases in four or five years. My somewhat sanguine expectations have been doomed to disappointment.* Only three additional cases have come to my attention. Of these, one pair has steadfastly refused to submit to examination, a second pair are still only about nine years of age and will not be ready for examination for some five years at least, and the third pair have just recently left us after spending two days in our laboratory taking tests. The data on this pair constitute the main material of the present report.

It now seems certain that there can be but few cases in existence of identical twins separated in infancy and reared apart. With Muller's single case and the four I have studied we have now a total of only five. In the course of time the cases may possibly mount up to ten, but I have very little hope of ever exceeding that number. The extreme rarity of such cases, together with the fact that they constitute the only human material in which the potencies of heredity and environment can be directly measured, renders it imperative that we should make a strong effort to obtain the maximum information about each case and to arrive at a correct diagnosis of the special environmental differences and their effects.

The Physical Environment of Mary and Mabel

These twins are in marked contrast with the other four pairs reared apart in that they have been more or less constantly in communication, visiting back and forth ever since early childhood. Until the last nine years, however, they have not been especially well acquainted, nor have they been much interested in each other. Only about nine years ago did they begin to be really companionable; now they exhibit a great mutual affection.

Mary and Mabel, now twenty-nine years old, were separated at five months of age, both being adopted by near relatives. They have always lived in the same part of the state of Ohio, less than one hundred miles apart. Hence the climatic features of the environment have been about the same. Both lived on farms until six years old, when Mary moved to a small town where she has resided ever since. She has never lived a very active, outdoor life, and she has done little manual labor. Since finishing high school she has clerked in a store daytimes and given piano lessons in the evenings.

Mabel has lived all her life on a prosperous 130 acre farm, leading the

* In correcting the proof of this paper I am surprised at the pessimistic tone of the introduction, for, since this paper went to press, certainly three and probably four new cases of identical twins reared apart have been found. It now seems probable that my goal of ten cases may soon be reached.

life of a typical energetic farm girl. She has enjoyed doing all sorts of farm work, such as milking, churning, feeding chickens and stock, and rather heavy household work. Her well-calloused hands bespoke her industry. She says that nothing could induce her to leave the farm.

Both twins have had the usual children's diseases. Mary had measles twice while in early grades, chickenpox when two or three, whooping cough before entering school, and she has had "influenza" almost annually during the winter. Mabel had measles once as a baby and again at eighteen years, whooping cough at about six years of age, and is rarely troubled with "influenza" or colds. The only difference of note in the health record is the rather bad record of frequent severe colds ("influenza") on Mary's part, and the almost complete freedom from colds on Mabel's part. This may possibly account partly for the very pronounced difference in physical condition seen in the twins at the present time (See Table I). Mabel, the farm girl, is very much more robust. She is an inch taller, a size larger in all physical measurements, has firm, hard muscles, and weighs 138½ pounds as compared with 110¾ for Mary, a difference of 27¾ pounds. This difference in weight amounts to nearly 25% of the total weight of Mary. Mary is distinctly under-weight, has inferior muscular development and lacks the muscular firmness of Mabel. Mabel has a clearer and somewhat ruddier complexion than Mary. Mabel walks with an erect posture and a rather masculine gait. Her movements are assured and rather quick. Mary is less erect, has a more ladylike walk, is slower in her movements and more inclined to sit still and avoid exertion

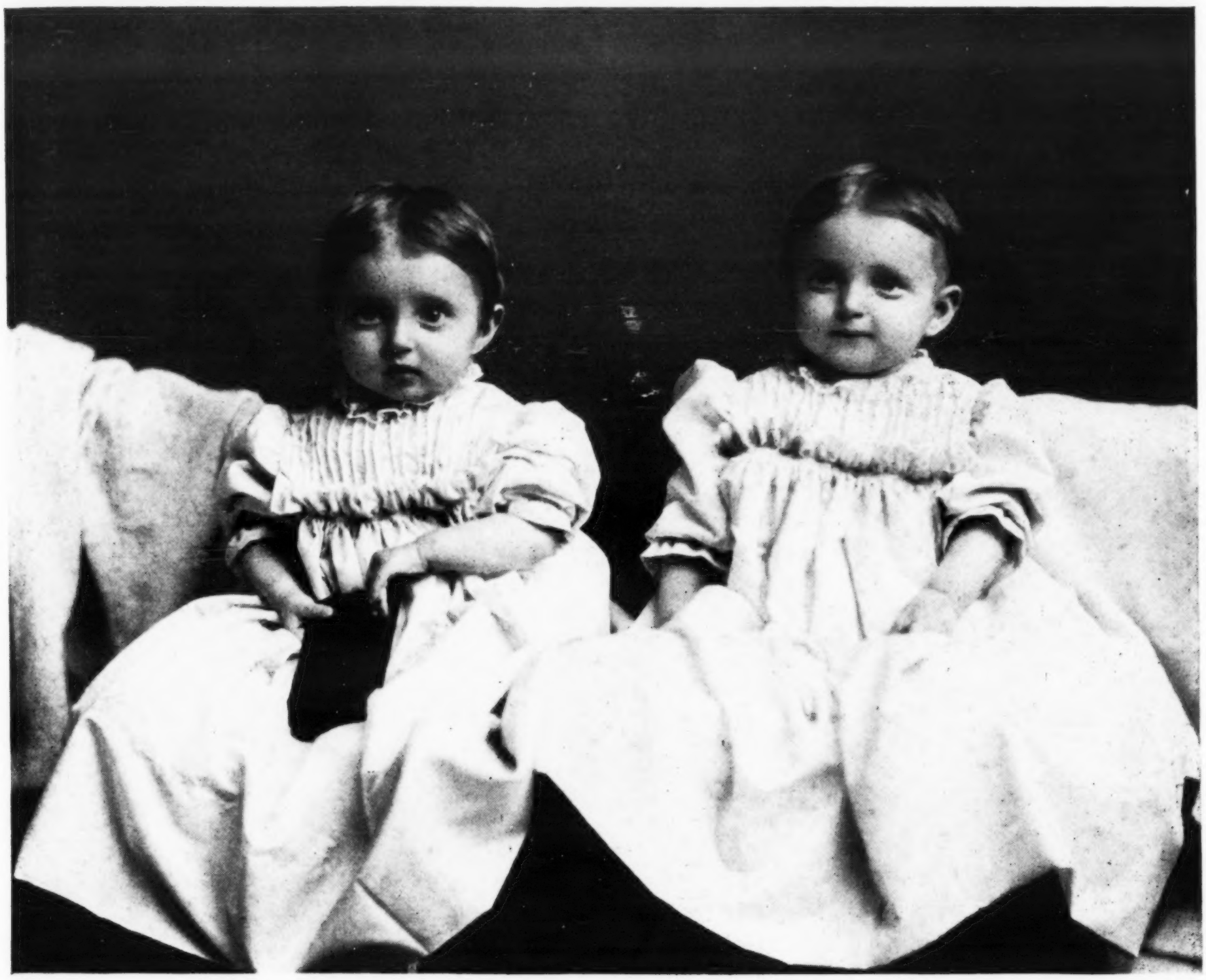
This contrast in physical condition is much greater than in any of the four earlier cases, though differences of considerable extent were noted in twins "A" and "O" and in twins "C" and "O".

Formal and Informal Educational Record of Mary and Mabel

Mary went through grade school in her home town and attended for three years the small home town high school, a school of about forty pupils. She had her final year in a city high school of sixteen hundred pupils. In grade school she preferred English and arithmetic, while in high school she preferred English and Latin. She was always in the upper twenty-five per cent of her class. Mary began the study of music, principally piano, at the age of about ten years and has taken this study rather seriously. She now gives piano lessons in the evenings. She has never had much time for books, her reading confined largely to popular magazines and newspapers. She was brought up in a religious environment. The other children in the family were ten or more years older than she, and did not seem very much like brothers and sisters to her.

Mabel went through the primary grades in the nearby country school. She started to attend high school in a neighboring city, but left after six weeks because she was needed at home to take care of her foster-mother's new baby. She does not remember being especially interested in any of her school studies. She seldom reads anything except magazines and newspapers. She was brought up in a family of children of not very different ages from her own, one foster brother about twenty months older and one about eight years older. She has always been treated as one of the family. The family is distinctly a religious one and Mabel has been much influenced by religious training.

There is no marked difference in economic status between the two families, both being in very good circumstances. Neither girl has traveled to any great extent, the trip from Ohio to Chicago being the longest either has ever taken. Other trips have been limited to one-day rides in automobiles or short trips by train to near-by towns.



MARY AND MABEL AS BABIES

Figure 1

At this age the twins were said to be indistinguishable. Today, at twenty-nine, Mary (left) the town girl, weighs 27¾ pounds less than Mabel, the country girl, but the evidence of monozygosity are conclusive. In spite of the pose in the picture both are right-handed. (See Figures 4-6.)

Are Mary and Mabel Monozygotic Twins?

The children were extremely similar as babies, hardly distinguishable when two years old when the second photograph (Figure 2) was taken. They continued to be extremely similar up till the time of the third photograph (Frontispiece), which was taken when they were seventeen. Since that time they have changed somewhat in appearance. Mary has her hair medium long and waved, while Mabel has a hair-cut practically like that of a man. The great difference in weight (27¾ pounds) increases the lack of resemblance. To the experienced student of twins, however, they are still recognizable as monozygotic twins, for they are practically identical in features, ears, teeth, voice, expression, and coloring of eyes and hair. Both are right-handed and both have clockwise hair-whorl on the right side of the crown. In this case, as in many others, the finger-print and palm-print evidences of monozygosity are conclusive. There is hardly a pair of twins in my collection whose dermatoglyphics more closely approximate identity than those of Mary and Mabel. The finger-prints are reproduced in Figure 6. The formulae are as follows:

	Left hands	Right hands
Mary:	$W^{u}.R^{w}.W.W.U$	$W^{u}.R^{w}.W^{u}.W.U$
Mabel:	$U^{w}.W^{u}.W^{u}.W.U$	$W^{u}.R^{w}.W^{u}.W.U$

The two right hands are more similar

MARY AND MABEL AT TWO YEARS

Figure 2

Their marked physical differences in later life had not appeared at this time.

than either right is like own left. In fact, the two right hands are very nearly identical, finger for finger. This is one excellent criterion of monozygosity. The total ridge count of Mary, using the Bonnevie method of rating, is eighty-four, while that of Mabel is eighty-three, a difference of only one point. This difference is very small even for monozygotic twins.

The palm patterns are even more strikingly similar than are the finger patterns (Figures 3 and 4). It was impossible to get perfect prints of Mabel's palms because of the large callouses. The blank space in the center of her left palm print (Figure 4) is due to large blister that had been peeled off. In spite of the imperfections in the prints their extra-

ordinary similarity will be obvious to the observer. The formulae of the palmar main lines and patterns are given in the legend to Figure 4.

In formulae the two right hands are exactly alike and the two left hands are exactly alike, but neither right is like the left of the same individual. Only monozygotic twins show correspondences of this sort. In fact, a close comparison of the palm prints should convince any one that these twins are monozygotic.

The facts that both girls are very positively right-handed, both have exactly similar clockwise hair whorls, that there are no indications at all of asymmetry reversal in palm or finger patterns, in dentition, or in bodily dimensions, indicate that these twins are true duplicates, not even mirror-image duplicates. They therefore belong to that group in which the asymmetry mechanism has played little if any part in producing differences. In this respect the present case is like my case II (twins "E" and "G") and like Muller's case. There can therefore be no question about the monozygotic origin of the twins Mary and Mabel.

Physical Resemblances and Difference

Something has already been said about the very pronounced differences in physical condition and in weight. One of my assistants, Miss Helen Pris, has recently examined and measured fifty left-handed girls for me, to discover whether there exist any bodily asymmetries correlated with handedness. Experienced in the use of anthropometric instruments, she made the measurements on Mary and Mabel that are given in Table I.

Note that Mabel is larger in every measurement. She is one inch taller, and shows greater bone length everywhere except in "alecranon to middle finger tip" of left hand, where she and her sister are equal. The greater differences are seen in the circumference measurements, where muscular development is reflected. Mabel's left fore arm is 1.4 cm. larger than Mary's, her right calf is 3.1 cm. larger. There is a very great difference in foot size, Mabel's left foot being 1 cm. longer and 1.2 cm. wider than Mary's, necessitating a size larger and a size wider shoe. The differences in hands are not so great, due possibly to the fact that Mary's hands have been used almost as much in piano playing as Mabel's in farm work.

Both girls have worn glasses for a long time, both being "far-sighted." Until quite recently they could use each other's glasses, but lately Mary's have been made "stronger" than Mabel's.

The teeth of both are of almost exactly the same shapes and color and are in equally good condition. Neither showed any definite irregularities. The same amount of repair had been done on both.

When examined, Mabel's hair, which was quite short, seemed a little softer and of a slightly lighter shade than Mary's, but she thinks that this difference is due to its having just been washed, while Mary's longer, waved hair had not been washed for a week. It was impossible to judge whether or not there was a real difference in hair color. At best the difference was slight, though noticeable.

At the age of seventeen there was very little difference in physical condition between Mary and Mabel. Hence the very great difference that now exists must have been the product of the last twelve years. This great physical difference is one of the most striking of the effects of different environments upon these duplicate hereditary constitutions. Noteworthy differences of the same sort were recorded for twins "A" and "O" and twins "C" and "O", but the differences were far less marked than in the present case.

Psychological Examinations

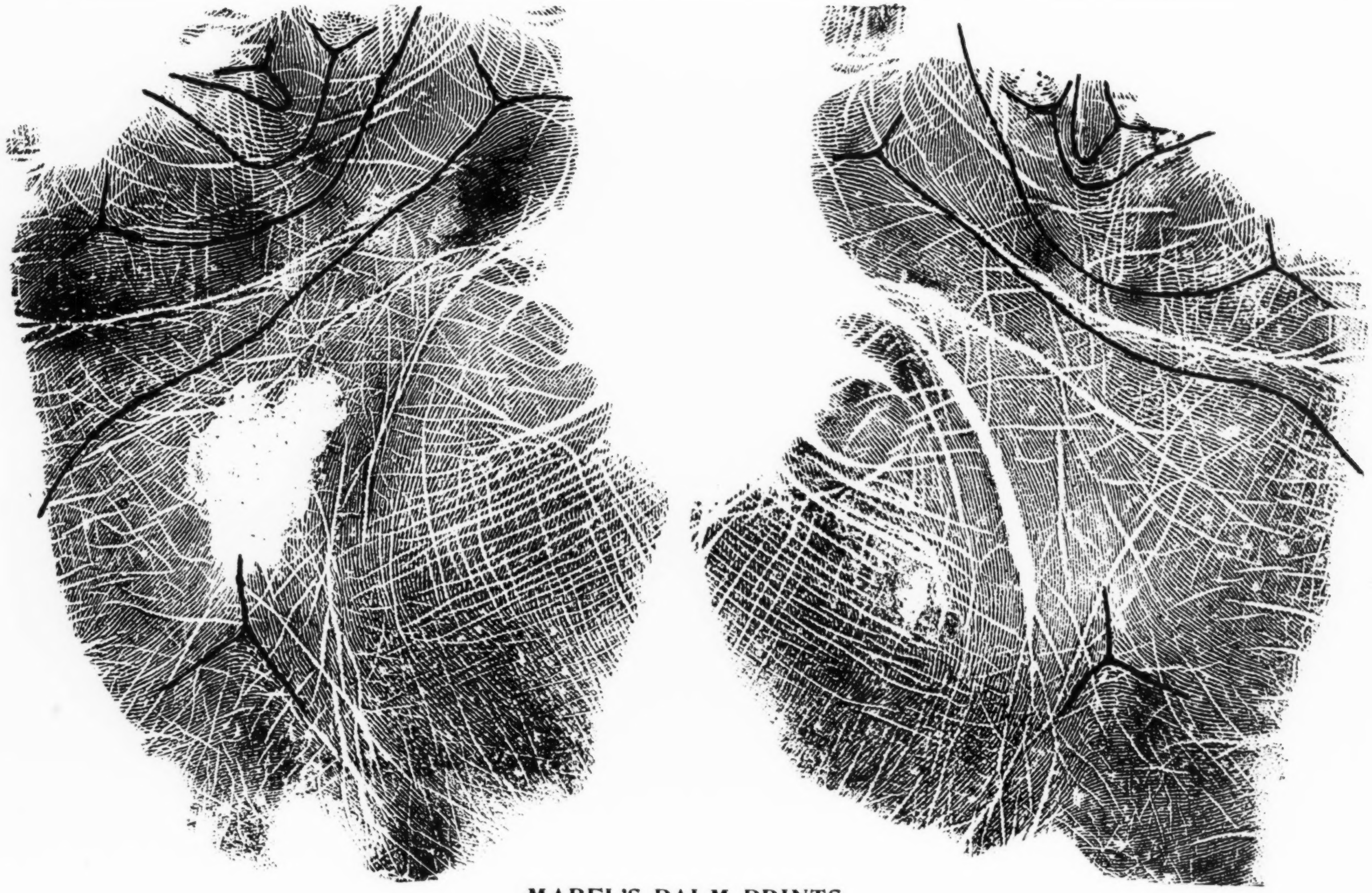
Practically the same tests were used for Mary and Mabel as for the other

MARY'S PALM PRINTS

Figure 3

The two right palms are strikingly similar as are also the two left palms. Neither right palm is as much like the left of the same individual as like the corresponding palm of the other individual.

of the same individual as like the corresponding palm of the other individual.



MABEL'S PALM PRINTS

Figure 4

Formulae for the palms is as follows:

Mary:	11.7.7.5'-t"-A^u/A^c.O.O.O.L	11.9.7.5'-t"-A^u/A^c.O.O.L.O
Mabel:	11.7.7.5'-t"-A^u/A^c.O.O.O.L	11.9.7.5'-t"-A^u/A^c.O.O.L.O

All four hands are decidedly similar, Mabel's being larger and stronger.

three cases except that in this case the motor tests for handedness were omitted because of lack of facilities at the time the tests were given. The tests were administered and rated as before by Mrs. Blythe Mitchell and confirmed by Dr. F. N. Freeman. The following tests were given and will be reported in this order:

1. Stanford-Binet Test.
2. Thurstone Psychological Examination Test.
3. Otis Self-Administering Test.
4. International Test—as worked out by Dr. Stuart C. Dodd.
5. Stanford Achievement Test.
6. Downey Will-Temperament Test.
7. Pressy X-O Test of Emotions.
8. Kent-Rosanoff Association Test.
9. Woodworth-Mathews Questionnaire of Emotional Stability.

The first five are classed as intelligence tests and the last four as temperamental and emotional tests.

I. Intelligence Tests

1. Stanford-Binet Test

Both girls worked steadily and without showing any signs of worry. The same amount of time was allowed to both. Mary's paper showed an I. Q. of 106.2, which is higher than that of any of the separated twins studied and within the range designated "normal." Mabel's I. Q. was 88.5, which, though higher than those of twins "E" and "G" and "A," is still in a group designated as somewhat "backward." The difference in I. Q. between Mary and Mabel is 17.7 points, or over 3.3 times as great as the average of fifty pairs of *identical* twins reared together, and even nearly twice as great as the average of fifty pairs of *fraternal* twins reared together, which is 9.9 points. This is the most striking difference yet found between identical twins. Mary was rated with a mental age of seventeen years and Mabel with one of fourteen years, two months. The difference is thirty-four months, while the average difference for fifty pairs of identical twins reared together is 8.4 months. Hence the difference in mental age between Mary and Mabel is 4.2 times as great as the average difference of fifty pairs of *identical* twins reared together and over twice as great as the average difference of fifty pairs of *fraternal* twins reared together, which is 15.9 months. This difference is even more striking than that expressed by the I. Q.

2. Thurstone Psychological Examination

This is a test commonly given at the University of Chicago to determine scholastic aptitude. It consists of five different elements testing five different types of mental ability. The following is the score of the twins as compared with the maximum possible:

SCORES

	Maximum	*Mabel*	*Mary*
Completion	80	14	20
Artificial language	74	0	35
Analogies	48	6	14
Arithmetic	80	16	16
Opposites	81	9	30
Totals	363	45	115

This test proved too difficult for both twins, but Mary handled it better than either of twins "C" and "O" of Case III and nearly as well as twin "O" of Case I. It will be remembered that twins "E" and "G" of Case II could do nothing at all with this test. The grade of zero made by Mabel in the artificial language test was due to her complete inability to understand the printed directions, while Mary understood what was wanted and did as much as she could in the time allowed. Mary had a percentile rank of 32, which means that she is 7 above the minimum of the second quartile, while Mabel had a percentile rank of 2, a very low rank indeed. Thirty per cent of all students taking this test fall between the rankings of Mary and Mabel. The difference here is not quite so great as was the case in twins "A" and "O" of Case I, but is nevertheless a very striking one. Since this test was not given to twins reared together no comparison is possible.

3. Otis Self-Administering Test

The results of this test may be tabulated as follows: Mary answered 48 questions, out of which 41 were correct; Mabel answered 44, out of which 30 were correct. The items of the test were classified as follows:

	Mabel	*Mary*
1. Hard directions	1	2
2. Arithmetic	5	6
3. Logical Relations	12	16
4. Opposites	5	6
5. Disarranged Sentences	0	0
6. Numbered Series Completion	1	1
7. Analogies	3	2
8. Proverbs	3	6
9. Syllogisms	0	2
10. Geometrical Relations	....	....
Totals	30	41
I. Q. Rating	91	111

There is a difference of fourteen points in I. Q., which is 3.1 times as great as the average difference between fifty pairs of *identical* twins reared together and over 1.5 times as great as that between fifty pairs of *fraternal* twins reared together. The difference between Mary and Mabel is in this test not quite as great as was that between twins "A" and "O" of Case I or that between twins "E" and "G" of Case II, but was four points greater than that between twins "C" and "O" of Case III.

4. International Test

This test is entirely pictorial and does not at all depend upon language. Hence it is perhaps more of a test of native brightness as distinguished from achievement.

SCORES

	Mabel	*Mary*
1. Cube counting and matching	8	12
2. Matching associated pictures	22	23
3. Pictorial similarities	11	6
4. Similarities in facial expression	16	15
5. Mazes	7	7
6. Rhythm series completion	11	12
7. Pictorial analogies	15	23
8. Narrative completion	4	4
Totals	94	102

The remarkable feature of this test is that Mabel is so nearly equal to Mary, although far behind in all the other intelligence tests. This is not because Mabel made a good showing, but because Mary made a particularly bad showing, considering her mental ability as demonstrated by the other tests. On the day when the tests were taken Mary had a cold and seemed very tired. This, rather than lack of ability, may account for her failure to make a good record in this test. Mabel made just about the score her mental rating in the other tests would lead us to expect, but yet persons with as high an I. Q. as Mary showed in the Stanford-Binet test should score at least 150 on the International Test. The International Test is a test of common sense rather than education, and it may well be that in this respect Mary is only slightly superior.

5. Stanford Achievement Test

The scores made in terms of "subject age" as shown below.*

The difference in educational age as shown by this test of educational achievement is thirty-four months,

*SCORES IN TERMS OF MONTHS OF EDUCATIONAL AGE

		Mabel	*Mary*
Reading	Sentence meaning	15 yrs., 10 mos.	17 yrs., 4 mos.
	Word meaning	15 yrs., 2 mos.	17 yrs., 1 mos.
	Both	15 yrs., 6 mos.	17 yrs., 2½ mos.
Arithmetic		11 yrs., 2 mos.	17 yrs., 6 mos.
Nature study		15 yrs., 7 mos.	16 yrs., 3 mos.
History and literature		13 yrs., 3 mos.	15 yrs., 7 mos.
Language usage		15 yrs., 4 mos.	18 yrs., 6 mos.
Spelling		15 yrs., 9 mos.	18 yrs., 4 mos.
Educational Age		14 yrs., 5 mos.	17 yrs., 3 mos.

which, remarkably enough, is exactly the same as was the "mental age" difference in the Stanford-Binet test, although the latter is supposed to be more of a native ability test than an achievement test. The results, however, both in this and in the other three cases in this series, make us suspect that both tests are measures of somewhat the same mental characteristics. Since the average divergence in mental age between individuals of a pair in fifty pairs of identical twins reared together was 6.2 months, the difference between Mabel and Mary is over 5.6 times as great. This difference is even somewhat greater than was found in the Stanford-Binet test.

II. Temperamental-Emotional Tests

6. Downey Will-Temperament Test

The differences between Mary and Mabel as shown by this test are graphically represented in the Will-Temperament Profile (Figure 5). Mary's total score is 76 and Mabel's 52, a difference of 24, or nearly 50 per cent of Mabel's total. Since a score of around 90 designates a strong personality and a score below 40 or 50 indicates some striking deficiency in will-temperament qualities, it is interesting to note that Mary has a moderately strong personality and Mabel is just above the level of deficiency. The greatest difference is in "coordination of impulses," where Mary ranks 10, the maximum, and Mabel 1, or nearly the minimum. On the other hand, they both took the maximum rating of 10 in "resistance to opposition." Both took 6 in "motor inhibition." In most other respects they were definitely unlike, and the whole test indicates great contrast in will-temperament. They are almost as unlike temperamentally as any two persons chosen at random would be expected to be.

7. Pressey X-O Tests

This test consists of four minor tests; the scores are shown below.*

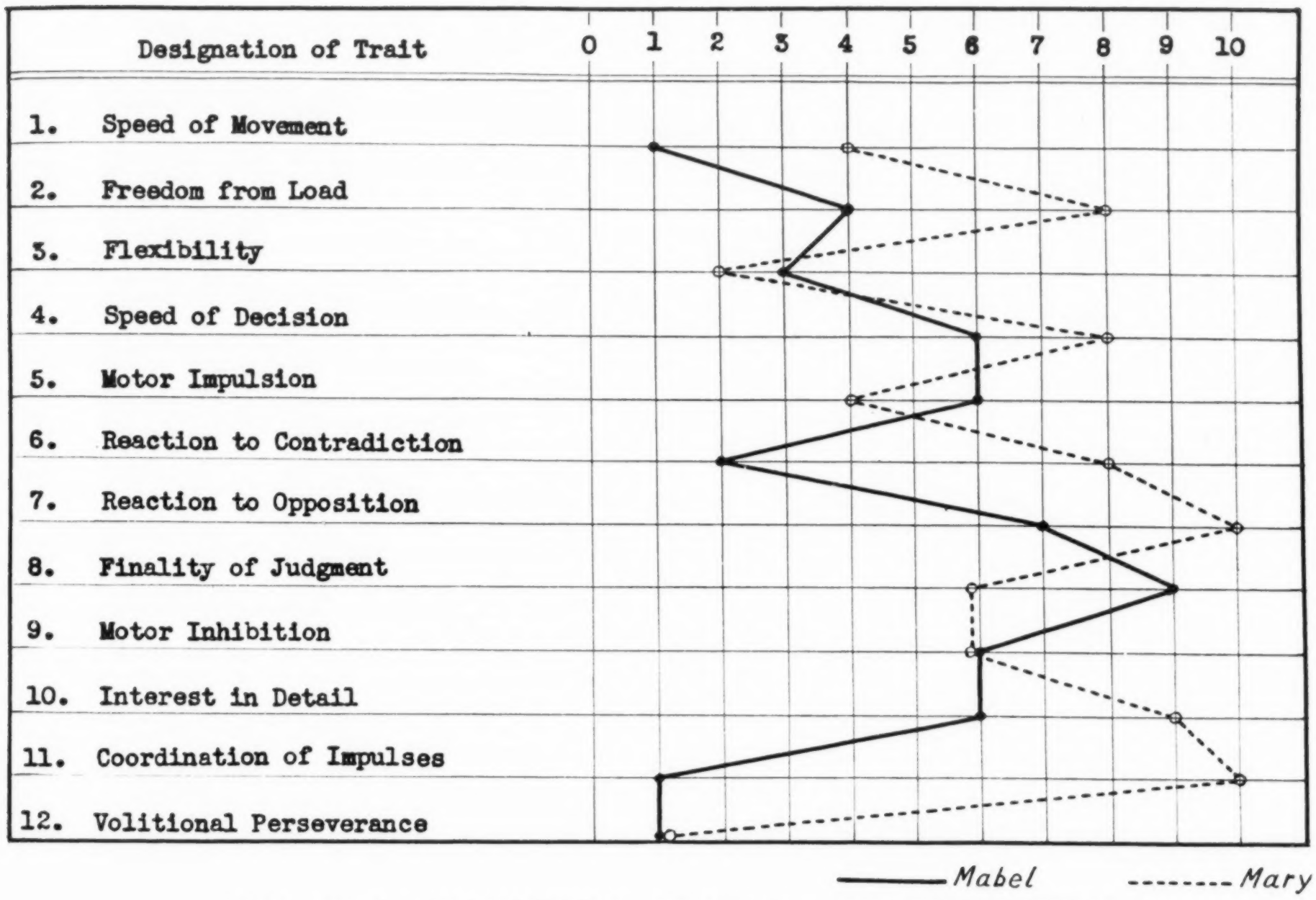
Type of words crossed out as "unpleasant"	*Mabel*	*Mary*
Disgust	11	18
Fear	14	19
Sex	6	11
Self-Feeling	12	19
Total	43	67

Mabel, brought up on a farm, is much less easily disturbed and more callous

---

* *Scores of Pressey X-O Tests.*

		Normal	*Mabel*	*Mary*
Test I. "Unpleasant" words	25th percentile	27		
	Median	41	43	67
	75th percentile	52		
Test II. "Words associated in mind with given word"	25th percentile	41		
	Median	55	33	52
	75th percentile	70		
Test III. "Things thought wrong"	25th percentile	60		
	Median	73	80	66
	75th percentile	86		
Test IV. "Things you have worried or felt nervous about"	25th percentile	33		
	Median	46	39	46
	75th percentile	55		
Total number of words crossed out in four tests	25th percentile	200		
	Median	230	195	231
	75th percentile	260		
The total deviation from mode in words circled	25th percentile	41.6		
	Median	47.2	53	59
	75th percentile	51.7		



THE "WILL-TEMPERED PROFILE" OF THE TWINS

Figure 5

The twins are almost as unlike tempermentally, as measured by this test, as two persons picked at random.

about unpleasant ideas than is Mary.

Worries classified	*Mabel*	*Mary*
Suspicious (paranoid)	4	7
Jumpy (neurotic)	7	11
Self-conscious (shut-in personality)	4	3
Melancholic	6	8
Hyperchondriacal	18	17
Total	39	46

Again Mabel is more normal, or stable, temperamentally, than Mary. On the whole, both girls are decidedly normal and wholesome in their reactions, but Mabel is superior in stability.

8. Kent-Rosanoff Association Test

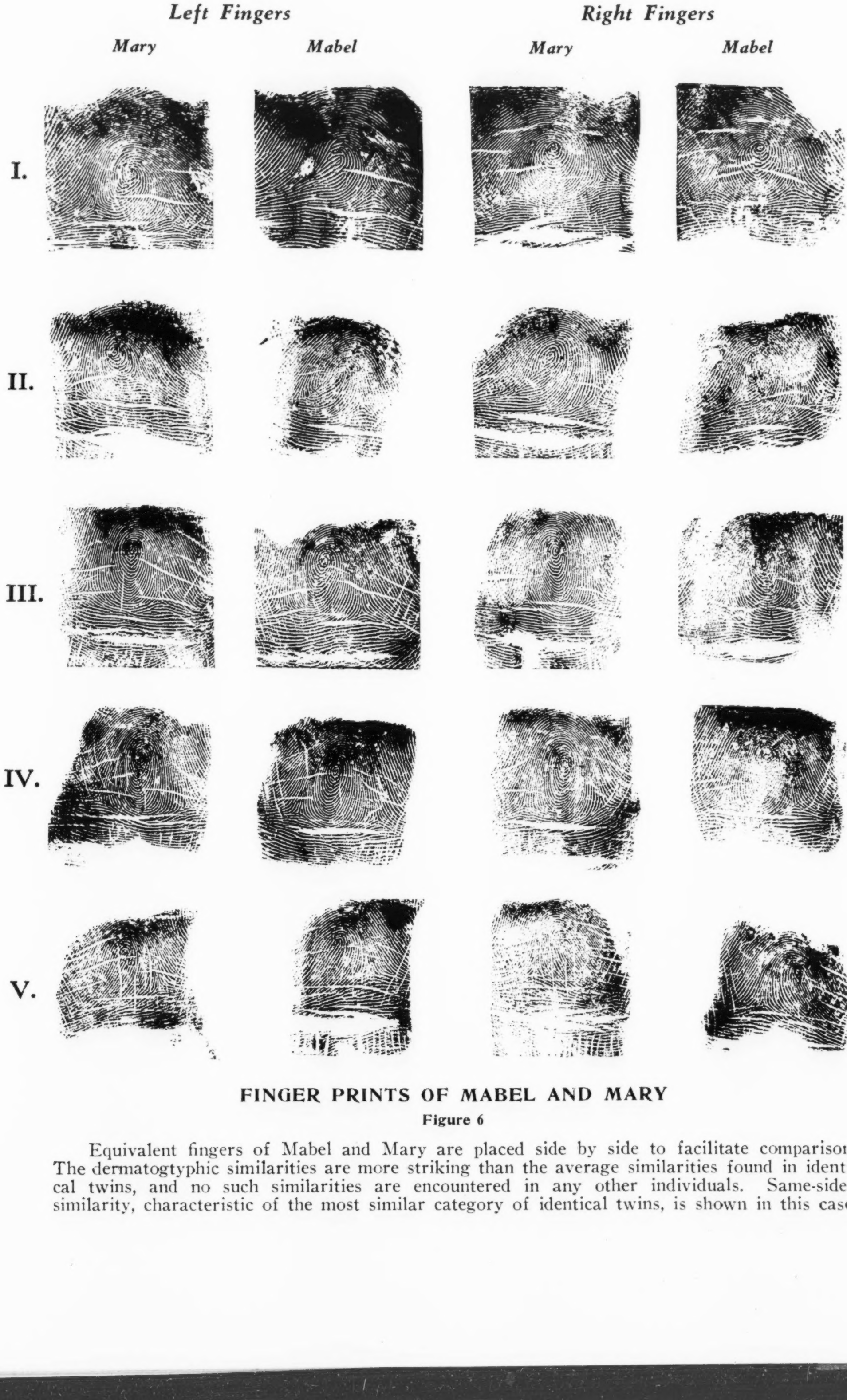
In this free association test (100 words) the twins made very similar records. Their responses were identical for 18 of the 100 words. Mabel gave the "normal" response to 95 of the 100 words, while the other 5 were "doubtful." Mary gave the "normal" response to 96 words, 3 were "doubtful," and 1 "individual." As based on the results with 1,000 normal subjects Mary rates 120.8, Mabel 129.8. Both rank high, but Mabel is a little higher. They are decidedly similar and normal.

9. Woodworth-Mathews Questionnaire of Emotional Stability

Mabel gave only 3 unfavorable responses, Mary 8. Both of these are very low numbers, but Mabel is more stable than Mary, as other tests had showed quite clearly. Of the 75 responses given by the two girls 68 were identical, indicating a high degree of similarity in emotional stability.

Summary of Case IV and General Discussion of all Cases Thus Far Studied

Mary and Mabel represent the most extreme differences so far observed in identical twins reared apart. This is astonishing in view of the facts that they live in the same climate and have been in communication with each other



FINGER PRINTS OF MABEL AND MARY

Figure 6

Equivalent fingers of Mabel and Mary are placed side by side to facilitate comparison. The dermatogtyphic similarities are more striking than the average similarities found in identical twins, and no such similarities are encountered in any other individuals. Same-sided similarity, characteristic of the most similar category of identical twins, is shown in this case.

since early childhood. The environmental differences are of two sorts, educational and occupational. Mary has had the superior educational experience, but Mabel the superior occupational experience.

Mary ranks much higher intellectually and in will-temperament, while Mabel is very decidedly superior physically and somewhat more stable and normal in her emotional reactions as brought out by the Pressy and Woodworth tests of emotional stability. Some of the emotional tests show strong resemblance, others show notable differences.

While in Cases I and II (twins "A" and "O" and twins "E" and "G") the twins were very different intellectually but very similar temperamentally, in my Case (twins "C" and "O") and Muller's case the twins were decidedly similar intellectually and very different temperamentally. Thus the four cases seemed to fall into two categories: one in which the intelligence was modified without greatly altering the temperament, the other in which the temperament was modified without greatly altering the intelligence. Also in two cases (twins "A" and "O" and twins "C" and "O") there was a pronounced difference in physical condition, while in the other two cases (twins "E" and "G" and Muller's case) there was no such difference.

The present case (Mary and Mabel) differs sharply from all previous cases in that they are strikingly different in all three respects: intellectually, temperamentally and physically. This is all the more remarkabe since the environmental differences are less striking than in at least three of the other cases.

While Mabel, the farm girl, on the basis of the intelligence tests given, ranks so much lower than Mary, she makes an impression upon those who meet her of being decidedly intelligent. When the twins were with us, both Dr. F. R. Lillie and I thought that Mabel was the abler of the two. She always took the lead and did the planning for the pair. She seemed much more communicative and took the major share in conversation. She seemed to dominate her sister in every way and gave the impression of having the stronger personality. Certainly she has as much "sense" as Mary, if we give that term its accepted usage. Her mind, however, has not been trained to the kind of performance required in intelligence tests. There may therefore be some ground for skepticism as to the validity of these tests as measures of mental ability. Undoubtedly they test more accurately the effects of training than of native endowment. The same is probably true of the temperament-emotional tests, in that they test the effects of emotional experience, rather than native temperament, if there be such a thing.

Nevertheless, the tests do show very definitely that different training, different experiences, and different modes of living profoundly affect the intellectual, temperamental and physical characteristics of the individual. They have a considerable share in determining a given person's mental powers, his character, and his physique—in a word, his individuality. Hence we may conclude that training, social contacts, and living conditions, the main elements of the human environment, actually do have an important influence in determining what kind of person one becomes.

But it would be a great mistake to overemphasize the environment at the expense of heredity, for the degree of similarity that persists in all these twins, even though the environment has worked upon them in diverse ways, is even more remarkable than are the differences noted. Moreover, many of their characteristics, such as coloring, dentition, hair characters, features, general bodily peculiarities, voice, gestures, palm and finger patterns, ears and other traits too numerous to mention, are evidently almost purely hereditary in the sense that they are unmodified by existing differences in the environment. Some of their other character differ-

ences, such as those of body weight, muscular development, state of complexion, mannerisms, gait, and a few other traits, seem to be largely environmentally determined, in the sense that they are very plastic and easily modified by actual differences in the environment.

Mental characteristics seem to fall between these extremes. They are sometimes greatly modified in one respect, sometimes in another respect, sometimes in several respects. There is no general rule that applies to all the five cases of twins so far studied. One can, however, reach some estimate as to the relative potency of heredity and environment in moulding mental traits by comparing the averages taken in certain tests by fifty pairs of identical twins reared together, fifty pairs of fraternal twins reared together, and the four cases of this series of identical twins reared apart. Let us compare the data of these three groups with respect to the Stanford-Binet test, the Otis Self-Administering Test, and the Stanford Achievement Test.

In the *Stanford-Binet Test* the fifty pairs of *identical* twins reared together showed an average difference in "mental age" of 8.4 months, and an average difference in I. Q. of 5.3 points. The fifty pairs of *fraternal* twins reared together showed an average difference in "mental age" of 15.9 months and an average difference in I. Q. of 9.9 points. In each item the identical twins were only about twice as similar as the fraternal twins. This in itself showed that heredity has a large influence in determining mental status, for the environment was the same in both kinds of twins.

The differences in the four cases of identical twins reared apart are as follows:

	Mental Age Difference	*I. Q. Difference*
Case I	23 months	12 points
Case II	23 months	12 points
Case III	3 months	2 points
Case IV	34 months	17.7 points
Total	83 months	43.7 points
Average	20.7 months	10.9 points

This means that the average difference between *identical* twins *reared apart* is over two and a half times as great as the average difference of identical twins *reared together* for mental age, and over twice as great for I. Q.

More striking even than this is the fact that the average difference in mental age between *identical twins* reared apart is 5.2 months greater, or nearly 30 per cent greater, than the average difference of *fraternal twins* reared together.

In the *Otis Self-Administering Test,* the average differences in I. Q. in fifty pairs of *identical* twins reared together was 4.5 points; for fifty pairs of *fraternal* twins reared together 9.2 points. Thus identical twins are more than twice as similar as fraternal twins, again demonstrating the power of heredity.

The difference in the four cases of identical twins reared apart are as follows:

	Difference in I. Q.
Case I	18 points
Case II	15 points
Case III	10 points
Case IV	14 points
Total	57 points
Average	14.25 points

In this test the average difference between identical twins *reared apart* is over three times as great as that between identical twins *reared together.* Also the average difference of *identical* twins reared apart is over one and a half times as great as that of *fraternal* twins reared together.

In the *Stanford Achievement Test* the average difference in mental age between fifty pairs of identical twins reared apart are as follows:

	Difference in Educational Age
Case I	19 months
Case II	38 months
Case III	16 months
Case IV	34 months
Total	107 months
Average	26.75 months

Thus the average difference in educational age in identical twins *reared apart* is over four times as great as that of identical twins *reared together.* In the Stanford-Binet and the Otis Self-Administering Tests, it should be remembered, the differences between identical twins reared apart were only 2 and 2½ times greater, respectively, than the average of identical twins reared together. Hence there is much greater difference when achievement is *specifically* measured than when some attempt is made to eliminate achievement. It will also be noted that the greatest differences in educational age appear in Cases II and IV, where there was a very pronounced difference in the educational experience of the twins; the greatest difference in educational age being in Case II, where there was the widest divergence in educational experience.

Conclusions

It is still too early to attempt to draw general conclusions on the basis of only five cases of identical twins reared apart, but some facts confront us that cannot be dodged. Perhaps the most disconcerting fact that has been revealed by the data is that *fraternal twins reared together are on the average about one and a half times more similar in mental rating, as judged by intelligence tests, than are identical twins reared apart.* This seems to mean that when the heredity is different and the environment the same, twins tend to become more similar than when the environment is different and the heredity is the same. Extreme environmentalists may see in this situation evidence that environment is more powerful in determining mental capacity than is heredity. I do not believe that this is true, and for several reasons. First, if environment were more powerful than heredity, *identical twins* reared together should not be twice as similar as *fraternal twins* reared together. Again, fraternal twins differ as much in mental characters as they do in physical.

Second, all the tests used to determine mental ability, except possibly the International Test, measure largely the effects of training. This tends to mask or cover up hereditary resemblances and differences, increasing the differences in cases where educational experiences are widely divergent and decreasing the hereditary differences (in fraternal twins) where educational experiences are alike. Thus the tests used tend to exaggerate the potency of the environment and to minimize the potency of heredity.

In spite of these weaknesses in method, however, the data at least warrant the conclusion that both heredity and environment play important rôles in determining mental status. Insofar as a person's mental status is measurable in terms of ability to perform well or poorly on intelligence tests, it seems fair to conclude from our data that differences in heredity and differences in environment are about equally responsible for the state of the mind of an individual at the time the tests were given.

On the other hand, since a large part of what is measured by intelligence tests is merely achievement, and not mental power, some will say we are not really measuring mental status at all. There is doubtless some justification in this criticism of intelligence tests, yet I cannot help but believe that one's individual mind, his mental rating, is at any time the product of his hereditary make-up and his training. If this be true, it is only fair to rate him according to this product.

In spite of all this apparent evidence that hereditary differences and environmental differences are of about equal potency in determining mental status, I have a deep-seated conviction, which I am unable completely to justify, that differences in heredity are considerably more influential, perhaps twice as influential, in determining one's mental status, as are differences in environment. If this were not true, why should identical twins reared together be more than twice as similar, on the

average, as are fraternal twins reared together?

In conclusion, let me once more emphasize the importance of locating and studying further cases of identical twins reared apart. If any such cases be reported to the writer, every effort will be made to reach and to study them.

Literature Cited

1. Muller, H. J. 1925. Mental Traits and Heredity. *Jour. Heredity,* Vol. 16, No. 12.

2. Newman, H. H. 1928. Studies of Human Twins.

I. Methods of Diagnosing Monozygotic and Dizygotic Twins. *Biol. Bull.* Vol. LV, No. 4.

II. Asymmetry Reversal, or Mirror-imaging, in Identical Twins. *Biol Bull.,* Vol. LV, No. 4.

3. ————. 1930. Palmar Dermatoglyphics in Twins. *Amer. Jour. Phys. Anthrop.,* Vol. 14, No. 3.

4. ————. 1930. The Finger Prints of Twins. *Jour. of Genetics,* Vol. XXIII, No. 3.

5. ————. 1930. Identical Twins Reared Apart. *Eugenics Review,* Vol. XXII, No. 1.

6. ————. 1929. Mental and Physical Traits of Identical Twins Reared Apart. Cases I, II, III. *Jour. Heredity,* Vol. XX, Nos. 2, 3 and 4.

TABLE I. Physical Characteristics of Mary and Mabel

	Mary	*Mabel*
Height	65¼ inches	66¾ inches
Weight	110¾ pounds	138½ pounds
Hair color	medium brown	a little lighter
Hair form	straight and soft	same
Iris color	medium brown	same
Skin color and texture	fair, but not so clear as Mabel's	fair and clear
Ear Shape	small, close to head	same
Handedness	right-handed in everything	same
Hair Whorl	on the right side of crown and clockwise	same
Features	nose long and narrow, mouth small, lips rather thin, chin prominent; features unusual	same except that face is fuller
Dentition	all teeth regular and in good condition for age	same
Alecranon to finger tip	L. 46.5 cm.; R. 46.0 cm.	L. 46.5 cm.; R. 46.3 cm.
Fibula	L. 37.8 cm.; R. 37.7 cm.	L. 38.6 cm.; R. 38.75 cm.
Circumference fore arm	L. 17.7 cm.; R. 17.65 cm.	L. 19.2 cm.; R. 19.1 cm.
Circumference calf	L. 31 cm.; R. 31.1 cm.	L. 34.1 cm.; R. 34 cm.
Foot length	L. 23.5 cm.; R. 23.4 cm.	L. 24.5 cm.; R. 24.2 cm.
Foot width	L. 7.8 cm; R. 7.7 cm.	L. 9.0 cm.; R. 8.8 cm.
Hand width	L. 7.4 cm.; R. 7.4 cm.	L. 7.7 cm.; R. 7.8 cm.
Eye defects	R. far-sighted, wears glasses	same, but glasses less strong
Use of eye in sighting	uses left eye	uses left eye

THE OPPORTUNITY OF SCIENCE

THE present economic debacle is a tragedy that in one way or another affects practically the entire human race. The economists and the "business surveys" are still, after two years, hailing each new "low" as the rock-bottom from which recovery springs. Each succeeding prophecy has an added note of plaintiveness, and it is evident that no mere cyclic variation is upon us, but a major economic and sociological disaster, that can only be met by brilliant and fundamental analysis and by drastic *and considered* action. Even palliatives are not being applied, and the fundamental problems are ignored or go unrecognized.

The disproportionally small Body Scientific should be the most promising source of the catalytic *ideas* which are our only hope of leavening the discouraging mass of tradition and inertia which holds us helpless in the present crisis. The following leading editorial appeared under the heading of "National Needs" in *Nature* (London) of November 14th. It is a remarkable discussion of some neglected aspects of the present situation. Its essentials transcend national boundaries, and with a few changes of names and places its message applies to every industrial nation today,—even to a nation over-stocked with wheat and cotton (but with millions underclothed and verging on starvation!).

While some of us may wonder just how scientific workers are to become "militant in every quarter" we must all agree that the need is there, and that it is generally not acknowledged. If a responsibility of this kind exists it applies especially to those whose discipline is heredity. All about us radical social and economic experiments are being suggested, nay demanded, and in practically every instance wholly without taking into account the quality of the people who are to form the basic element of these experiments. The failure to mention heredity in the recently promulgated "Children's Charter" is after all only a symptom of the almost universal attitude today. The Body Social either does not know of the demonstrated facts of heredity, or it dare not face them. It prefers to cling desperately to witch-doctor emotional formulations that are pathetically inadequate to exorcise the destructive tendencies with which we have been brought face to face by a machine age, and an essentially inhuman economic system.

Professor Armstrong's call to scientific thought and action is issued none too soon. Every scientific worker will appreciate the difficulties of heeding it, but this does not absolve us from a responsibility which must somehow be met. "The hungry sheep look up and are not fed." Perhaps science has no message for hungry sheep; if this is the case we may well ask whether science is really a technique for discovering and interpreting important facts, or has there been a fateful neglect of the field of human welfare?

If science is able to produce only machines, and if its generalizations deal mainly with such trivialities, from the practical point of view of racial welfare, as nebulae or protons, we may question whether science is really more than another epiphytic excrescence on a social organism that in many other respects is cooperative only in theory and dangerously parasitic in fact. If we have social insight we must deliver our message; if not in words of one syllable, at least in a form that on the average is less reminiscent of Taine's cynical remark about the use of language to conceal our thoughts. "Plan or Perish."—the alternatives are clear, and they appear to be tragically urgent. Can science, or rather scientists, show the way?—EDITOR.

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THE present sore trouble of the world, which has long been surely coming upon us owing to the inconsidered action of all nations, will not be without its compensations, if we be led to probe into the causes and to reorganise our operations upon considered lines.

The call is upon us all to turn our attention to affairs of State. Scientific workers especially have to recognize that they have been selfish in their too exclusive devotion to experimental study and the immediate development of their discoveries; that they have soared entirely above the heads of the community and in no way prepared the masses to understand the profound changes brought about in our life by the scientific forces at work in industry. Brains and brawn were never so far apart as now. Although this is the case, it was never so clear that a wise socialism is foreshadowed as the only possible way of avoiding the downfall of our civilization. In some way or other, the nations must come to work together. Competitive industry, as we have known it in the past, is ceasing to be possible: it pays no one and is but a disguised civil war. Mechanisation is bringing about its own defeat: the cost of displacing human labour is becoming prohibitive. Man is ever there; capital will not long be, at present rates of taxation: we shall soon be forced to return to *manu*factures.

The chief duty before us clearly is—to make all men work: a machine which is idle has no right to be. Nature itself ever works and necessarily dies if she cannot. Man alone of her works is ceasing to be natural and fast becoming a mere parasite.

The country is now in the hands of a Government elected upon a National ticket; the popular expectation is, that it will be Rational and rise superior to party. There is, however, an ominous preponderance of men of rigid outlook bearing political labels; few are known to profess a belief in government by scientific methods. Probably the Prime Minister alone can attach any real meaning to the term 'scientific.' He was long an attendant at Royal Institution lectures and grew up in a scientific atmosphere. Very remarkable, at the recent Faraday celebration in Queen's Hall, was the entirely sympathetic way in which he entered into the spirit of the occasion, outshining all other speakers in clearness of perception of the service rendered to the world by Faraday, especially the moral value of the example set by this great experimentalist. His father-in-law, we know, was the most sympathetic of Faraday's biographers. Probably Sir John Simon comes next to Mr. McDonald. He at least has breadth of outlook and a severely logical mind.

It is much to be feared that the men who have taken upon themselves to govern us cannot possibly fathom the depth of present-day world activities: the overwhelming complexity of the issues; the subtle problems they present; the hopeless difficulty of meeting the naturally selfish dictates of human nature. Earl Grey being all but out of action, there is no prophet in the field of politics. We need a Disraeli, a man of imagination, able to grasp our modern problems and be a constructive leader. If the recent elections have shown one thing more than another, it is that the country is prepared to follow a clear lead. In this particular, Mr. MacDonald and his small band of devoted followers have set a noble example.

Nothing could be more definitely painted upon the wall than the failure of our public schools to train the ruling classes in any proper way. The "science" introduced into them has been to no purpose—no effective teaching has been given in the logic of method. Consequently, the calculated practice of scientific argument—the habit of sound scientific thought—plays no part in our affairs; it has no considered place in our Civil Service. This is one of the matters of urgency, calling for fullest consideration, at the present moment. Unless and until our universities and schools are brought into harmony with the times, no real progress can well be made. Oxford most needs reformation: the present neglect of a broad culture by the University is a national danger. As to the schools, it should be deemed a criminal act to bring up a

boy or girl upon literary study alone, without training in the judicial method.

Our schools still teach little more than the worship of words and those largely words of the past. The men in charge of them, with few exceptions, have no feeling for the wide issues of practice and scientific leadership. We are a strange people: intensely practical in our general outlook, we place ourselves in the hands of those who cannot possibly become masters of the intricate situation which confronts us. Teachers as a class in no way grasp the responsibilities of their position, let alone the dangers of the times. They are too much of one school and, with rare exceptions, of an unadventurous type. Complaint of the inflexible nature of the material they produce is rampant everywhere.

Lafcadio Hearn, writing from Japan, in August, 1893, in an outspoken letter to Ellwood Hendrick, after remarking how terribly tragic modern life is becoming, directs attention to its hopeless contradictions. These, he says,

"can only be recognized and reconciled through a profound knowledge of social conditions, not in the abstract only but in the most complex operations. This is the theoretical recognition. The practical recognition requires special hereditary gifts—intuitions—instincts—powers. Mere education in business alone won't do. That only makes servants. Masters must be natural masters of men. Life is an intellectual battle but not a battle to be fought out by mere chess-combinations. It is also a battle of characters . . . . . I do not see much likelihood of moral development . . . . . morals have been at a standstill since the beginning of history: we have made no apparent progress in that. Then comes the question, Are we not developing immorally?"

There can be little doubt as to the answer. The Hollywood atmosphere in which the masses now live—the scorching, motor habit, developed as a mere means of escaping from the boredom of mental vacuity—the condition of the Press, which for the most part has no soul beyond sexuality and sport: all these things are proof sufficient that there is no real intellectual progress to be recorded. The masses have learnt to read—but "the hungry sheep look up and are not fed." The body scientific— those who hold the keys of knowledge—makes no calculated effort to provide them with food. The literary class, as a body, has no message; brought up upon words alone, with myopic uncultivated vision, it can only use words to describe the obvious.

Not so long ago, starting from Huxley and Herbert Spencer, a body of men representative of natural science, in its various branches, made a determined effort to galvanize the schools into practical scientific activity and make education an introduction to life: the attempt has been a failure. Scarce any of the band remain. Modern scientific workers—the professional researchers—no longer take interest in such matters. Occasionally someone kicks: Prof. Irvine Masson is the latest example. The bookmen hold the field: what public conscience there may be is stilled by free education and scholarship grants. We have little right to complain of politicians, so long as we make no effort to train them to their office by bringing about the revolution which every thinking man knows to be long overdue in our school system.

Meanwhile the industrial shoe pinches terribly. There isn't enough leather to make it a comfortable fit. We are so pampered into the belief that we can live on industrialism, that no real thought is given to the problem as a whole. The fetish of what is supposed to be cheapness is worshipped without any consideration of its consequences. No sense of the meaning and value of agriculture has been bred into the community.

The mathematicians can discuss the Unseen Universe with great popular effect. Yet they make no attempt to stem the ignorance of the money-changers or help them to devise a rational system of banking which will enable us to do without the gold we cannot have wherewith to back the counters issued as money—so that commerce may be controlled and its operations made facile, not the sport of spec-

ulators. The multitude obviously does not understand the meaning of the term *standard*: the professed economists have not the wide equipment that is needed for their task.

Men now need to be so trained that they learn to work together—without losing their souls. No trade today is free; some combine is at work which prevents each one from being fair. So long ago as 1894, Hearn could write to Hendrick prophetically:

"The tyranny of the future must be that of Organization: the monopoly, the trust, the combination, the associated company . . . . . much more powerful than the robber-baron . . . . .these are infinitely less human—having no souls."

Hearn spoke as an artist, of course. Still, his plaint is justified in a tyranny such as is being exercised over milk production, by the great combines now coming into action as universal purveyors. Water has long since passed into public control: milk some day perhaps will be seen to be of even greater consequence and cared for properly.

We have no food sense worth calling a sense: biology to this end is not taught in the schools; women decline to cook and are deluding themselves into a belief in canned foods. Our ignorance of all essential things is monstrous. Scared by a few bacteria, we systematically spoil our milk. We are even threatened with synthetic food. Machinery, using the sunshine of past ages, is to put the nose of our present sun out of joint and make the farmer a back number. Our only salvation is the natural horse sense that is in us.

* * * * *

In future, the scientific worker, to be worthy of the name, must justify himself through social service in the first instance. Our situation is so grave that he must be militant without delay and in every quarter.—H. E. A.

Nature: (London) Nov. 14, 1931.

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The Science of Human Affairs the Most Difficult

There is another aspect of the relation of science to the community. The public conception of science is commonly limited to the mathematical, physical and chemical sciences, with the many departments of biology and their applications and in recent years, psychology. The great field of social studies is usually, at least in Europe, regarded as outside the field of science, with the single exception of economics. However, if prediction be the test of science, eonomics has not been, in the last few years, conspicuously successful.

It has been the aim of many thinkers to build up a science of human society, to embrace not only economics but all the activities of man. Sociology, to use the name coined originally by Comte, is the most difficult of the sciences, because it deals with phenomena of far greater complexity than any of the physisal or biologicol sciences. Few of its principles have yet been established, and it must still be regarded as a science in the making, but its importance is such as to deserve the attention of all students, in spite of the urgent claims made on their time by their chosen specialism. I believe that this fact is more generally recognized in America than in Europe, but nowhere is the treatment of social problems, such as those of politics and finance, scientific to the extent that would be desired by the sociologist, and it would seem that those who already employ scientific methods of reasoning with success in one field could render service in bringing about their extension to others.—Desch, Cecil H. Pure and Applied Science. *Science,* Vol. 74, No. 1925—Friday, Nov. 20, 1931. Page 500-1.

A PINK-FRUITED LEMON

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THE discovery of a striking fruit with color characteristics that are apparently new and that have a startling appearance is a matter of general interest. An illustration of this fact will be presented in this note which briefly describes a pink-fruited lemon and its origin so far as known.

A variegated limb variation was found by the writer in 1911 in an Eureka lemon tree located on the Chase plantation near Corona, California. The characteristics of this bud variation and progeny trees that were propagated from it were described in 1920.*

The variegated Eureka lemon parent-limb variation and its progeny trees have characteristics, both as regards foliage and fruits, similar to those of the normal Eureka limbs and trees excepting in the color of the bark, leaves and fruits. In the variegated bud sport the bark of the young branches is variegated with fine stripes of varying shades of green and straw color. The leaves are oval in shape, obtuse, of medium size, fairly abundant in number and variegated in color as shown in Figure 9. The white and green sections of the leaves occur in areas of variable size and shape, in some cases the leaves being almost or wholly white, as can be seen in the twig shown in the lower right side of the illustration, while in other instances they are nearly green.

The fruits are oblong in shape, of medium size, rough or ridged in texture and have thin rinds. The rag is tender, and the juice is abundant but lacking somewhat in acidity. The seeds are similar to those of fruits of the Eureka strain. The lemons have a striped appearance, usually with alternate green and white areas. This appearance is correlated with a ridged condition, the ridges being usually green in color while the depressed spaces are white. The leaves, fruits and bark of the progeny trees of this strain originating as a bud sport have a similar variegated appearance. Trees of this strain are not as productive as those of the comparable normal Eureka strain. The very thin rinds and rough appearance of the fruits as well as the relatively low yields of the trees makes this strain of very doubtful commercial value but it is rather widely planted in some citrus growing areas of the Southwest for ornamental purposes. It has been found by the writer during the past twenty years occuring as individual fruit, limb and entire-tree variations of the Eureka lemon.

During the National Orange Show that was held at San Bernardino, California in February 1931, the writer noticed a typical variegated lemon among a collection of citrus fruit sports that was presented by the American Fruit Growers, Inc., as a feature of their general fruit exhibit. Upon examination this variegated lemon was found to have a pink-appearing rind and flesh that was not particularly apparent under the artificial light in the show building and it was largely unnoticed on account of the many strange specimens of citrus fruits with which it was grouped.

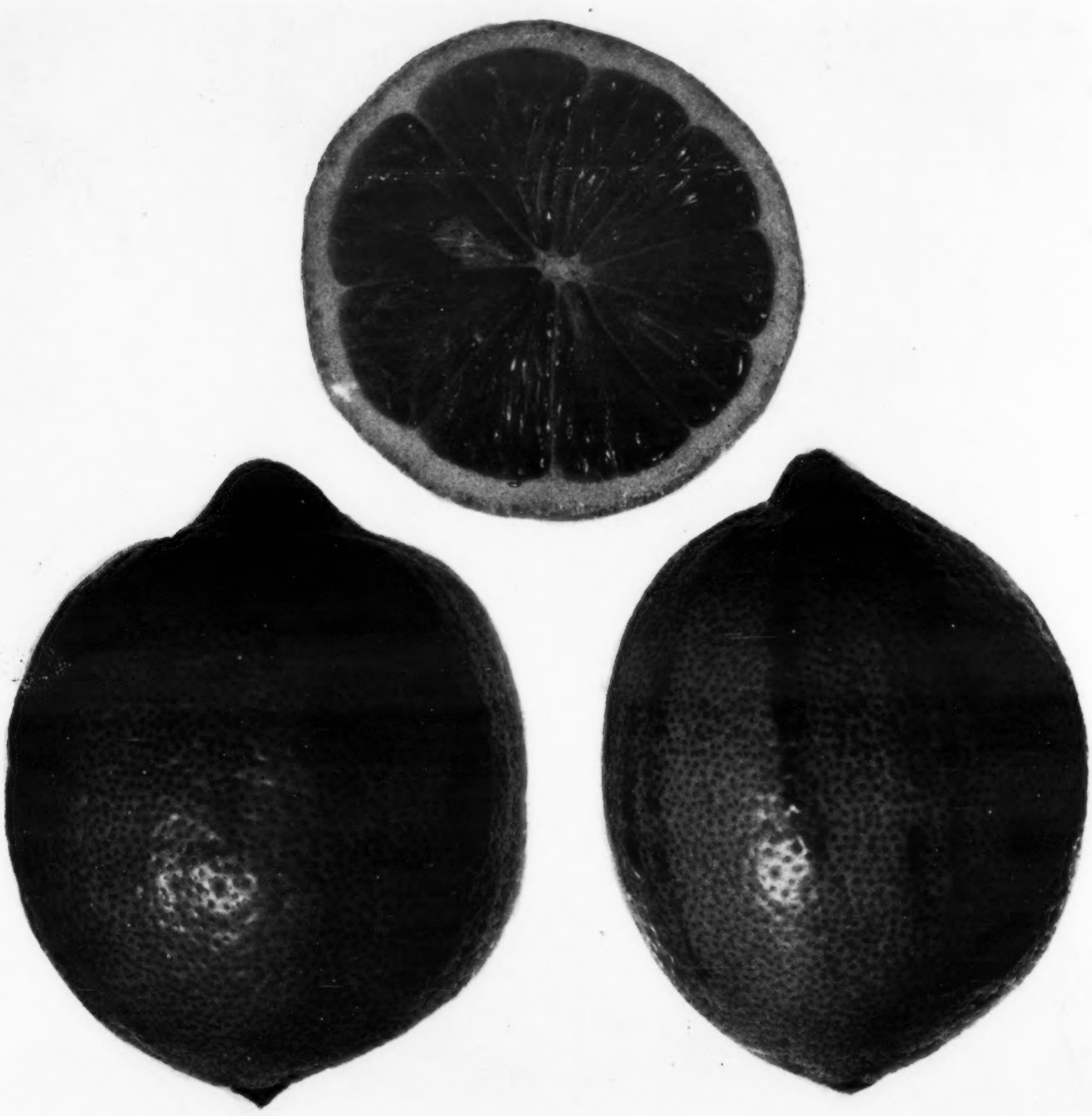
From information supplied by officials of American Fruit Growers, Inc., the parent tree from which this pink lemon was picked was located in a small planting of citrus trees in the grounds of the winter home of Mr.

*Shamel, A. D., et al., Citrus Fruit Improvement: A Study of Bud Variation in the Eureka Lemon, *U. S. D. A.* Bulletin 813, Washington, 1920.

LEAVES OF PINK-FRUITED LEMON

Figure 7

Showing range of variegation of leaves, from entirely green to completely white.



PINK LEMONS

Figure 8

Typical fruits of pink-fruited Eureka lemon from parent tre located at Burbank, Calif. The fruits, as they approach maturity have pink colored rinds, flesh and juice. This is the first pink-fruited variation of the Eureka lemon that has been reported. Photographed April 20, 1931.

D. W. Field at Burbank, California. This tree, the writer found on April 20, 1931, is identical in appearance and all characteristics observed with those of the Variegated Eureka lemon bud variation described in the foregoing paragraphs excepting that the fruits develop a decidedly pink color of rind, flesh and juice as they approach maturity (Fig. 8).

The pink-fruited Variegated Eureka lemon tree is about fifteen years old but it has not been possible to trace its origin definitely. It stands among neighboring orange and lemon trees of several varieties, some of which are obviously of the standard commercial varieties while others are unknown to the writer. It is a healthy, fine tree and apparently as productive as the Variegated Eureka lemon trees now under observation by the writer in

VARIEGATED LEAVES AND FRUITS

Figure 9

Variegated Eureka lemon limb variation in an otherwise normal Eureka lemon tree located on the Chase plantation, Corona, Calif. Such variegated sports are not uncommon in the Eureka variety, a number having been observed in the last twenty years. The pink-fruited form recently discovered resembles this more common variation except in color. Photographed August 21, 1918.

several Southern California lemon groves.

The pink color of the rind, flesh and juice was not observed in the young fruits but became increasingly evident in the older lemons on the tree until when the fruits had reached commercial size, this pink, reddish, or "blood" color is very conspicuous (Figure 8.)

In the pink-fruited tree several small branches were found that were apparently wholly green in color of bark, leaves and fruit but as it is very difficult to determine definitely this condition, the wholly green characteristics of these branches remain somewhat in doubt. Other small branches were observed where the stems and leaves were nearly if not wholly white but none of them bore fruits.

The pink color in the lemons is the only apparent characteristic that distinguishes this interesting variation from the Variegated Eureka lemons that have been under observation for years. From their study the writer believes that the pink-fruited tree is a bud sport of the Eureka lemon and is another illustration of the occurrence of striking bud variations in this variety of citrus fruit.

Budwood was obtained from the parent tree by the writer and inserted in sour orange seedlings at the Citrus Experiment Station of the University of California during the last week of April, 1931. It is planned to study the resulting progeny trees in connection with those of the Variegated Eureka lemon bud variation mentioned in the early paragraphs of this paper.

Books Received

BOOKS are acknowledged in this column as received, and such acknoweldgment must be regarded as sufficient return for the courtesy of the sender. As far as space permits, books that contain material of special interest to the readers of the JOURNAL *will be reviewed in later numbers.*

REPORT OF THE NINTH CONFERENCE OF THE INTERNATIONAL FEDERATION OF EUGENIC ORGANIZATIONS — Farnham, Dorset, England, September 11th to 15th, 1930. Pp. 100. Published by the I. F. E. O. Hon. Administ. Sec.: C. B. S. Hodson, 406 Fulham Road, London, England.

What's to do about eugenics in many corners of the globe, with papers on detailed problems and on specific traits: eye color; blood groups; racial psychology; race crossing, etc., etc.

LA THEORIE PHYSCIO-CHEHIQUE DE LA SEXUALITE, *by* PH. JOYET-LAVERGNE. Pp. 102. Five chapters. Price, 10 fr. G. Doin & Cie., Paris. 1932.

Some more sex-determination *theories.*

CHILDREN'S BEHAVIOR PROBLEMS. A Statistical Study Based upon 5,000 Children Examined Consecutively at the Illinois Institute for Juvenile Research, *by* LUTON ACKERSON, Research Psychologist, Institute of Juvenile Research and Behavior Research Fund, Chicago. Pp. 268. Fifteen Chapters. 57 Figures. Price, $4.00. University of Chicago Press, Chicago. 1931.

All the things that 4,592 kids could think of to do (one of them did nearly three pages in small type, from *bad table manners* to *vomiting spells* and *plenty* between), correlated with *IQ*, *CA* and what have you. The subhead of the book is "Incidence, Genetic and Intellectual Factors," but neither "genetic," "hereditary," "family," nor "inheritance" appears in the index. There are two pages of conclusions which we couldn't seem to get anywhere with, but the "study is being continued with a large number of possible causal factors," Better luck next time!

CHILDREN WHO RUN ON ALL FOURS, And Other Animal-like Behaviors in the Human Child, *by* ALES HRDLICKA, M.D., ScD., D.Sc.NAT., Curator, Division of Physical Anthropology, U. S. National Museum, Smithsonian Institution. Pp. 418. 13 Plates, 27 Figures. Price, $5.00. Whittlesey House, McGraw Hill Book Co., New York. 1931.

That's one thing those Chicago kids didn't think of. If they had there would have been another chapter. That our racial family history has a bearing on this way of getting around is a fruitful hypothesis, and a similar hunch, buttressed by a few thousand family histories might have proved more than all those graphs and statistics in the Chicago study.

POPULAR QUESTIONS ANSWERED, *by* GEORGE W. STIMSON. Pp. 426. Price, $2.00. George Sully & Co., Inc., New York. 1930.

Debunking a few hundred superstitions and accounting for a few hundred queer practices. Quite a hodge-podge, but an interesting collection of the absurd in mental luggage with which we are wont to load ourselves. Among them many biological superstitions, on the average quite well handled.

ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION, Showing the Operations, Expenditures, and Condition of the Institution for the Year Ending June 30, 1930. Pp. 650. Price, $2.00. U. S. Government Printing Office, Washington. 1931.

Articles by Davenport on the Mechanism of Organic Evolution, and on Extra Chromosomes by Blakeslee are of especial interest genetically.

THE CRIMINAL, THE JUDGE, AND THE PUBLIC, A Psychological Analysis, *by* FRANZ ALEXANDER, M. D., Visiting Professor of Psychoanalysis at the University of Chicago and HUGO STAUB, Attorney at Law, Berlin. Translated from the German by Gregory Zilboorg, M. D., Bloomingdale Hospital, White Plains, N. Y. Pp. 238. 11 Parts, 16 Chapters. Price, $2.50. The Macmillan Co., New York. 1931.

Ever since Cain (the working out of whose Oedipus complex is made plain on P. 205), those of us who commit murder and whatnot appear to be behaving exactly according to Freud, and if we get adequately "psyched" in time we will be so busy with our subconscious we won't have time to be murdering folks.

THE DECLINING BIRTH RATE IN ROTTERDAM, A Statistical Analysis of the Drop in the Number of Children in 24,664 Rotterdam Families during the Last 50 Years, *by* J. SANDERS, M. D. Pp. 180. 29 Charts. Price, 6 Guilders. Martinus Nijhoff, The Hague. 1931.

What nearly twenty-five thousand Dutch families have done in the way of perpetuating the race in the last half-century. The present incumbents are only 30 per cent as efficient as their forebears, and this is definitely not due to decreased biological fertility. A statistical study that *has been productive*, and of many extremely interesting conclusions.

THE ANTHROPOMETRY OF THE AMERICAN NEGRO, *by* MELVILLE J. HERSKOVITS. Pp. 283. Eight Chapters. 102 Tables, 34 Figures. Price, $4.00. Columbia University Press, New York. 1930.

Plenty of statistics, proving that more are necessary, or that in the absence of any special purpose just data don't get us very far.

A SHORT HISTORY OF THE AMERICAN NEGRO, *by* BENJAMIN BRAWLEY. Pp. 311. Eighteen chapters. 3rd Revised Edition. Price, $2.00. The Macmillan Co., New York. 1931.

Up from slavery, and beyond. "It is also increasingly evident that the real leadership of the world is not a matter of race, or even of professed religion, but of principle."—Oh, yes?

Is Education Improving?

EDUCATION, CRIME, AND SOCIAL PROGRESS, *by* WILLIAM C. BAGLEY. Pp. 150. 8 Chapters. Price $1.20. New York, The Macmillan Co. 1931.

It is the main thesis of the book that in spite of the vast number of young Americans subjected to the presumably beneficent attentions of today's so celebrated alchemist, the educator, the results in terms of good citizenship and social progress are very disappointing.

The measurement of our social limitations is made in terms of crime ratio comparisons with England, France, and even with puny and supposedly benighted nations, all of whom we greatly

excel in the amount and probably, too, in the variety of our crime. The author neatly forestalls any explanation of this in terms of the breakdown of formal religion by J. R. Miner's statistical demonstration of how the free thinking northern states are outdone, in a general breaking of the Commandments, and especially the tenth, by the God-fearing South. For good measure the author adds divorce rate comparisons in which the two great political unions (U. S. and U. S. S. R.) easily lead the field in the granting of legal dissolutions of marital ties.

While agreeing that we must look for the ultimate cause of crime and divorce in the individualistic selfishness and hedonism of the modern American, the author's contention is that our educators have been recreant in their duty of instilling a sense of personal obligation and an appreciation of the necessities of order, discipline, and effort in the young. Rather there has been a mad pursuit of new methods of teaching, and new curricula, full of promises of intellectual mastery with minimum effort; so many roads that wind and wind and lead nowhither. It is heartening, to the reviewer, to have an educator thus expose the twaddle which so often passes for modern educational progress.

The other matter discussed, second in terms of textual space although it is the first introduced to the reader, is that of technological unemployment. Professor Bagley feels that education should better fit people for proper utilization of leisure and for different sorts of employment. Here, again, mastery of basic subjects rather than a superficial knowledge of soon-to-be-obsolete specialties is the desideratum.

The statistical facts presented in the book cannot, of course, be denied. Most people will agree, at least in principle, with the inferences which Professor Bagley has made. It is, I believe, at this juncture that one little mouse asks: "And who is going to bell the cat?" The method by which Professor Bagley's ideals are to be attained is not very obvious at present, in spite of the commendable analysis of the problem with which he confronts us.

R. R. Huestis,
University of Oregon.

Inspirational Heredity

LIKE BREEDS LIKE, A Non-Technical Treatise Covering Heredity, Live Stock Breeding and Eugenics, *by* Harry H. Cook. Pp. 383. 57 Chapters. 77 Illustrations, 21 Tables. Price, $3.50. Research Department, Sans Aloi's Jersey Farm, Ontario, California. 1931.

THREE hundred and eighty-three pages of unbridled enthusiasm for the breeder's art and of reiterated expressions of confidence in the importance of heredity. Non-critical throughout and full of an excess of superlatives almost to the point of incoherence in places, the book seems to be a lineal descendant of Wiggam's "*Fruit of the Family Tree*," not one whit diminished in enthusiasm or desire to evangelize nor one bit increased in the scrutiny and verification given to each statement. The biblical allusions are abundant and may materially enliven an otherwise idle hour for one to whom this book is handy. It is delightful to see a man devote one chapter to paleolithic and neolithic man and the next chapter to tracing the descent of the present races of man from Noah and his three sons. The author is somewhat puzzled at how to derive from a single family such diverse races of mankind as now exist and partially satisfies himself with the conclusion that Ham in order to have been the progenitor of such races as the negroes and the primitive Australians (!) must have been from a dark skinned mother and therefore was only a half brother to Shem and Japheth. One of the interesting features of the book is the pedigree of Moses showing 6.5% inbreeding and tracing in twelve lines to

Terah. Moses had 8.2% of the blood of Terah although the latter was a great, great, great, great grandfather in the nearest line. (These calculations of course rest upon accepting at face value the story of Pharaoh's daughter as to how she came in possession of Moses!)

More than half of the book is devoted to sketchy histories and descriptions of common breeds of livestock. There are many typographical errors such as zebra where zebu was obviously intended, a reference to the Clydesdale stallion, Boron of Buchlyvie, and the statement on page 259 that "—sperm from the semen of the male ignites with the ovum of the female—."

At any rate the author, who is a successful breeder of jersey cattle, believes in the power and majesty of the law of heredity (although he never does just exactly define the law!) and the book will appeal to some as easier to read than a more coherent one, technically accurate in details would have been.

JAY L. LUSH,
Iowa State College.

Heredity and Diabetes—A Medical View

Prof. Marcel Labbé, in an address delivered before the Academy of Medicine, Paris, discussed the hereditability of diabetes, in which field he has had a long experience. According to the majority of writers, such hereditability, long since recognized, exists in 25 per cent of the cases. A distinction is made between hereditary and familial diabetes, but in reality they have the same significance. Diabetes comes under an hereditary system that has functioned for centuries according to the laws of Mendel. Labbé distinguishes benign diabetes without denutrition, and grave diabetes with denutrition. The former is usually acquired as a result of prolonged superalimentation; the latter without known cause. Under the various forms of familial diabetes may be distinguished diabetes due to an hereditary influence and diabetes due to wrong familial habits of eating, which lead to superalimentation. In a hundred cases, Labbé and Landau found twenty-three cases of hereditary diabetes. Evidences of heredity are found in 35 per cent of the grave cases of diabetes and in 20 per cent of the benign cases. The rôle of paternal heredity is much greater than that of maternal heredity, for the reason that a diabetic woman rarely has children. The hereditary influence is, however, sometimes overcome, to a certain extent. Labbé stated that he had seen six children born of mothers with grave diabetes. While these children have not yet shown diabetic symptoms, it is possible that the disease will appear later. The hereditability of diabetes now is conceived of as the transmission of a functional insufficiency of the islands of Langerhans. It is difficult to understand why the insufficiency of the islands becomes apparent at different ages and remains latent for varying lengths of time. Hereditary transmission entails certain deductions with regard to the marriage of persons with diabetes. Some physicians prohibit marriage. In Laddé's opinion, in the majority of cases, diabetic persons who take good care of themselves may marry. Young diabetic women should, however, avoid pregnancy, as it is always dangerous for them.—*Jour. Amer. Med. Assoc.*, Oct. 10, 1931.

FERTILE GYNANDROMORPHS IN HABROBRACON

P. W. WHITING and EDWARD J. WENSTRUP*

A MOSIAC WASP

Figure 10

A mosaic male produced by a virgin mother heterozygous for two factors, one causing the antennae to be shortened and tapering, the other causing the basal segments of the antennae to be yellow. The right antenna is shortened and yellow at base, the left is normal. Such mosaics are due to the taking part in development of the polar body, in which one set of chromosomes is ordinarily discarded in the formation of an egg cell. In a case such as this, one-half the wasp is the genetic complement of the other half, in all genes for which the mother was heterozygous. × 21.

IN the parasitic wasp, *Habrobracon*, unfertilized eggs develop into males which are haploid in chromosome constitution and resemble their mothers in hereditary traits. Fertilized eggs usually produce females which are diploid and of biparental inheritance. Virgin females, heterozygous for anv

*Zoology Department, University of Pittsburgh, Pittsburgh, Pa., and Biology Department, St. Vincent College, Latrobe, Pa., respectively.

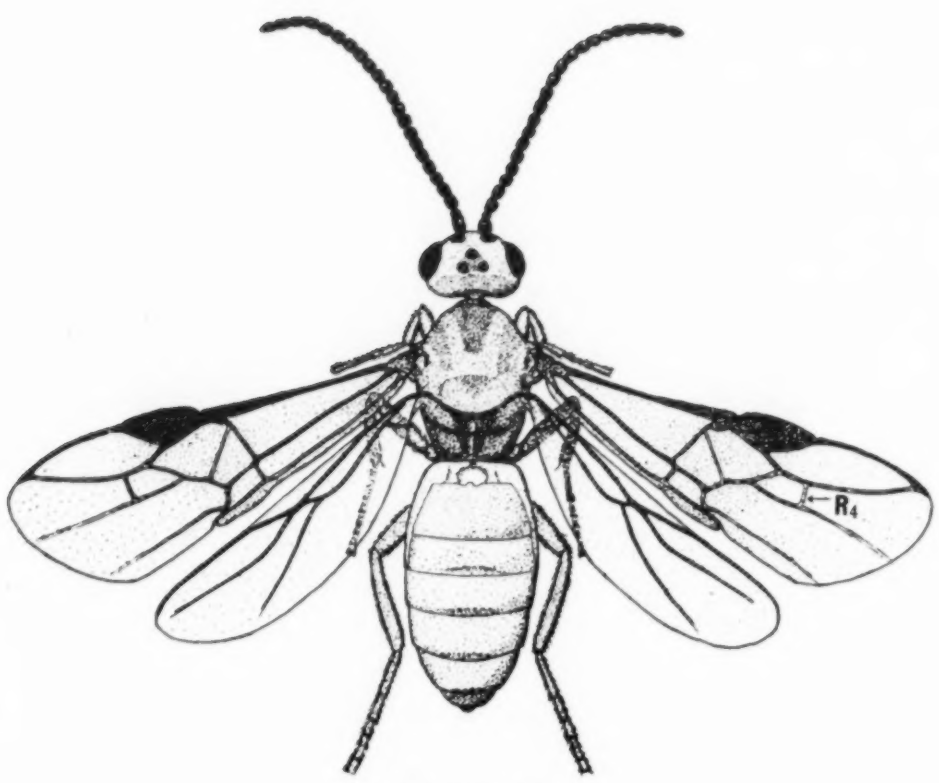


Figure 11

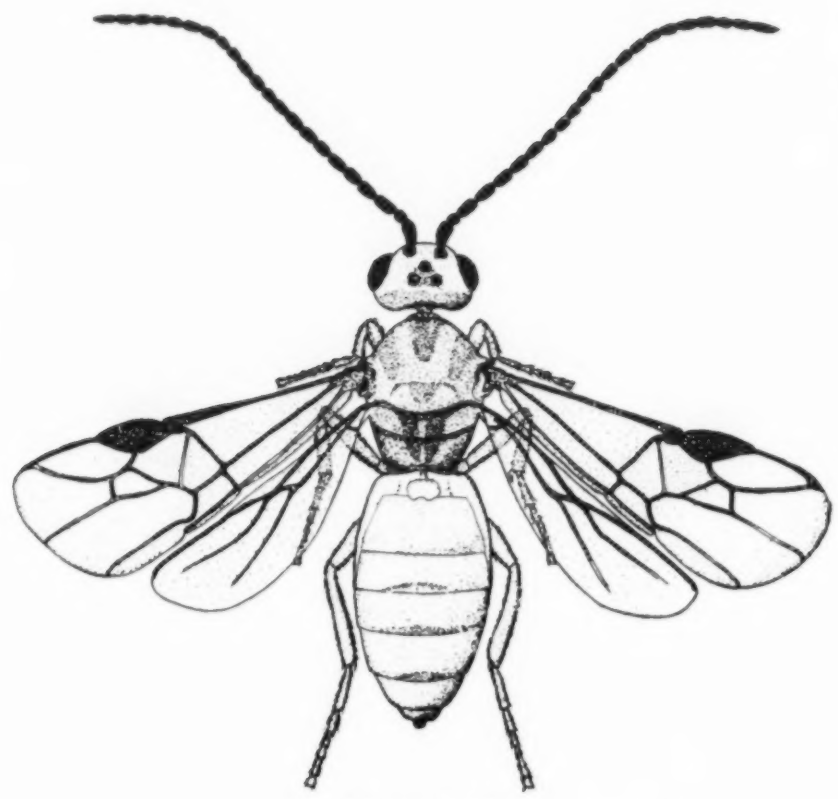


Figure 12

NORMAL AND MUTANT WASPS

At left the normal form; at right the mutant form called *long*. The factor long causes lengthening of antennal segments. The wings are curved ventrally toward the tip and also shortened distally as may be seen in the radial cell above vein R_4. × 10.

one of the numerous mutant factors which have been found, ordinarily produce males of the two expected types in approximately equal numbers.

Unfertilized eggs from heterozygous mothers occasionally develop into mosaic males. A male mosaic shows in different parts of his body, diverse traits inherited from his mother. We have abundant genetic evidence that these males arise from binucleate eggs differing in allelomorphic factors. One of the nuclei corresponds with the second polar body, the other with the reduced egg nucleus. An understanding of the origin of these males is essential to an understanding of the nature of gynandromorphs. The frequency of their occurrence is about one in 500 to one in 5,000 males bred from heterozygotes, varying according to stocks involved and other conditions.

Figure 10 illustrates such a mosaic (No. 516) from a mother heterozygous for a recessive factor causing shortening and tapering of antennae, *ta,* and a dominant causing the basal antennal segments to be yellow, *My*. One nucleus of the binucleate egg giving rise to this male contained factors *Ta* and *my* for normal antenna, the others *ta* and *My* for tapering, yellow antenna. Both nuclei took part in parthenogenetic cleavage, the former in this case producing the left half of the body, the latter the right.

Occasionally a sex-mosaic or gynandromorph is found among the progeny of a mated female. The frequency of occurrence of gynandromorphs among females is comparable with that of male mosaics among males. Male parts of gynandromorphs bear the hereditary characters of the mother while female parts show the dominant traits of both parents. It may then be said that these female parts have, like females, two parents, while the male parts have, like males, a mother but no father. Evidence shows that gynandromorphs arise when one of the nuclei of a binucleate egg is fertilized.

In comparison with females, males have longer antennae, readily noted with the unaided eye; larger ocelli and smaller abdominal sternites. Genitalia of the female include a pair of sensory appendages and a sting. Males average somewhat darker in general body pigment than females and have smaller legs and wings but these more

variable characters cannot ordinarily be used to distinguish sex.

Figure 11 shows a normal male and Figure 12 a male of the mutant form long, *l*, so called because the antennal segments are considerably lengthened. This factor also has the effect of shortening the wings distally and causing them to curve ventrally rather than being flat. The shortening is especially noticeable in the radial cell above vein R_4.

Figure 13*A* shows a gynandromorph (No. 348) with male head and female abdomen. The mother was homozygous for long, *l*, while the father was non-long, *L*. Antennae are male and haploid with segments lengthened due to factor *l*. The wings, however, show no shortening nor ventral curvature and the radial cell is of normal length. Influence of factor *l* is therefore obscured in the wings by the dominant allelomorph, *L*, brought in by the sperm and the wings may be regarded as female like the abdomen. Both parents had ivory eyes and consequently the gynandromorph shows this trait. Gynandromorphs with male heads and female abdomens have been found more frequently than other types.

Figure 13*B* shows a gynandromorph (No. 514) found by C. H. Bostian. This insect has female head and predominantly male abdomen. There are, however, female islands in the abdomen as may be seen in the photograph; the second right sternite and the first and third left are large and unmistakably female. The mother had cantaloup, *c*, eyes while the father was orange, *o*. Cantaloup and orange are both light, reddish and somewhat variable and stand in marked contrast to the jet black type reconstituted in the heterozygous, *OoCc*, female eyes and ocelli of the gynandromorph.

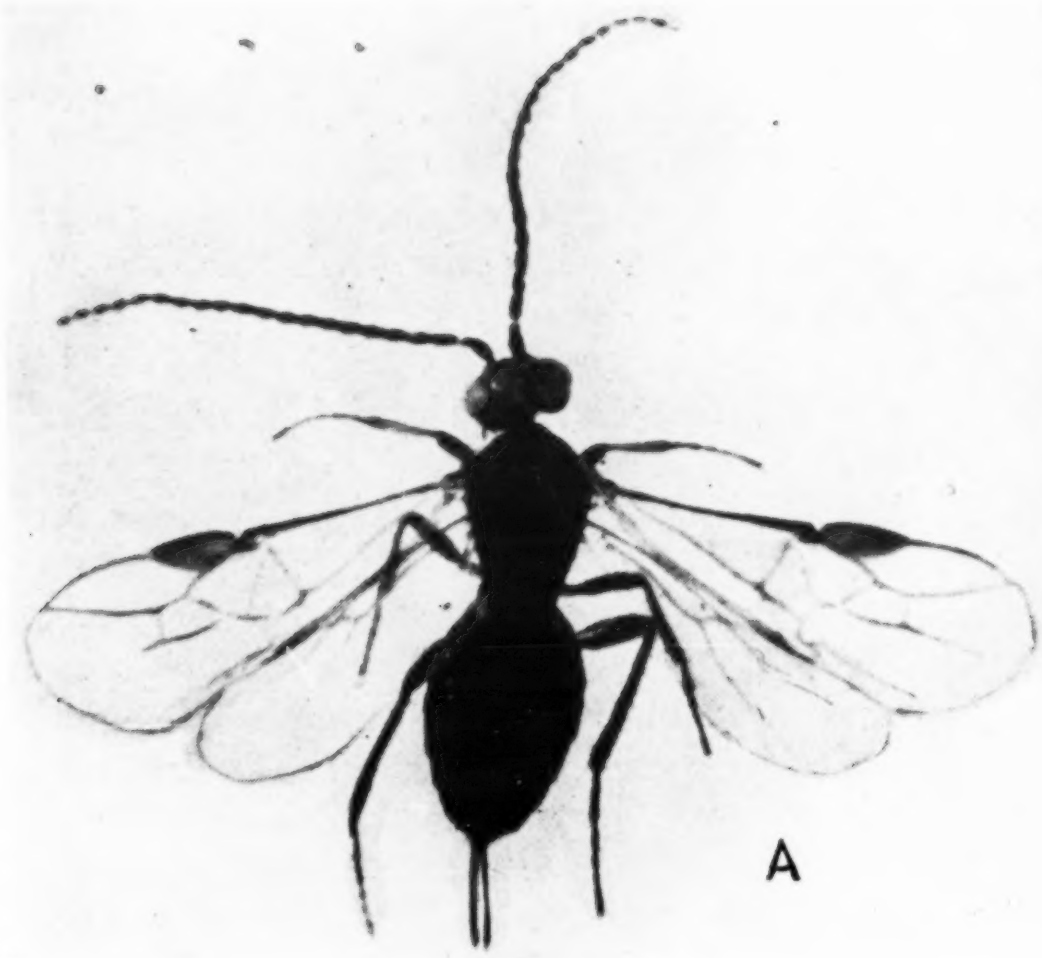
A third type of gynandromorph (No. 446) is shown in Figure 13*C*. The right side of the body is male, the left female, as may be seen in antennal length, in wing size, in abdominal sternites and in genitalia (Figure 14). This individual came from a cross of orange female with defective wing vein R_4 (Figure 11) by type male with black eyes and normal R_4 vein. The right eye is orange, the left black; ocelli are orange and male. Left primary wing has slight break in R_4 and is somewhat larger than right. It is therefore probably diploid, female, and heterozygous, *Dd*, while right primary with its greater break in R_4 is haploid, male, and defective, *d*, genetically. Secondary wings are symmetrical. The sperm brought in the dominant allelomorphs to orange and to defective and consequently the female side is *OoDd* while the male side is derived from the unfertilized nucleus *od*.

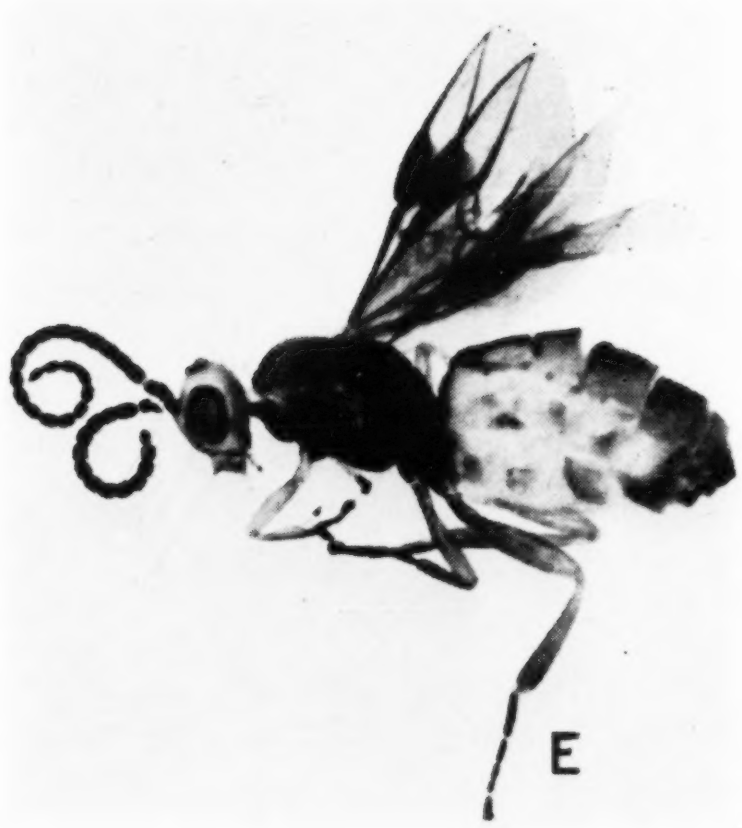
Instincts of Gynandromorphs Governed by the Head

Reproductive instincts of gynandromorphs are governed largely by the head and consequently it has been impossible to secure offspring from most of them. If the head is male, the insect with a female abdomen will attempt vainly to mate with females but shows no interest in caterpillars, will not sting them, feed on them or lay eggs. In fact the eggs of such an insect degenerate for want of the proper nourishment, the juice of the host caterpillar. A gynandromorph with female head will, on the other hand, attempt to sting caterpillars, despite its lack of a sting, and to lay eggs, despite its male abdomen. Of the three gynandromorphs described, the second only (No. 514) was tested. This specimen was female in instinct, indifferent to females and reacting to caterpillars.

In all of the 52 gynandromorphs tested only six have been found with instincts and genitalia of the same sex. These will now be discussed in some detail.

A gynandromorph (No. 425) found

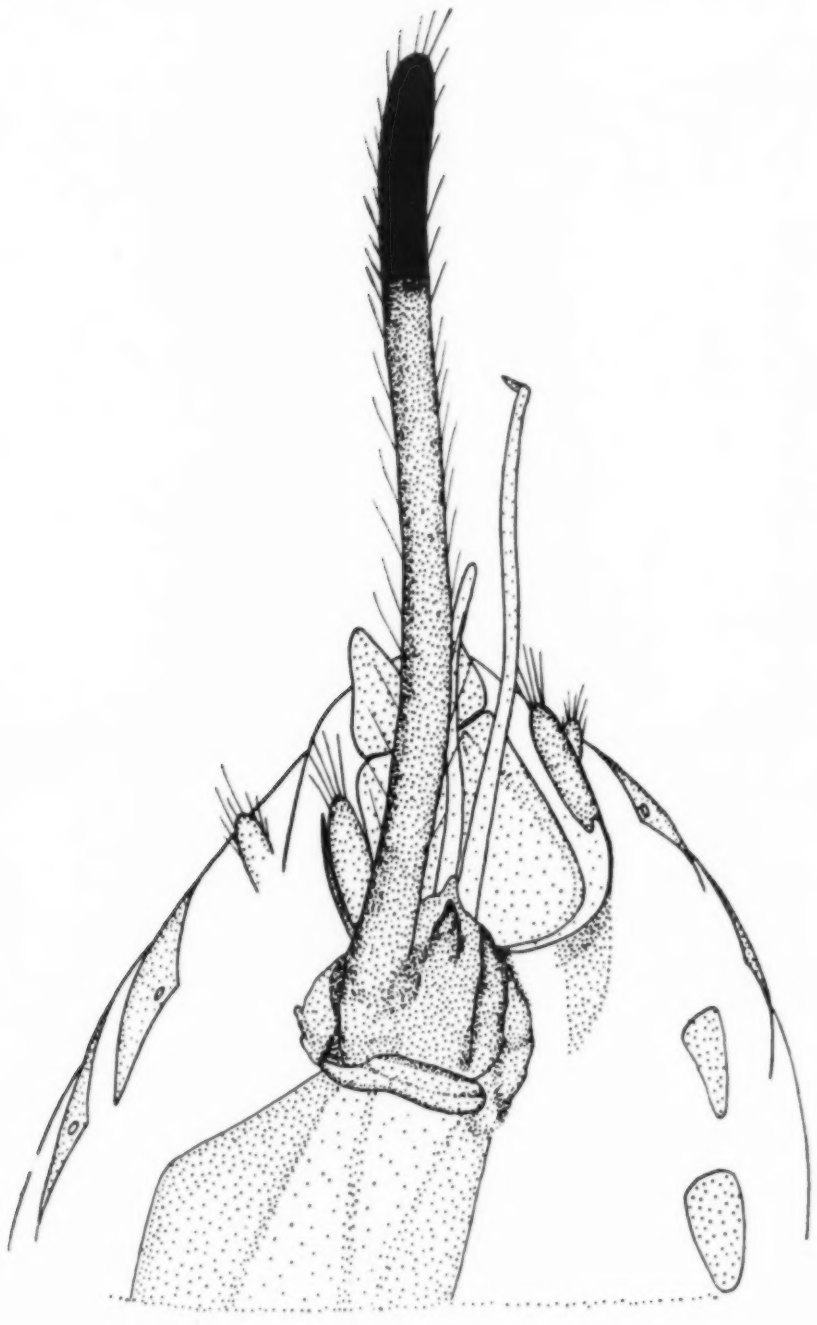




MIXED MALE AND FEMALE

Figure 13

Gynandromorphs showing various combinations of male and female components. Detailed descriptions of each of these will be found on the opposite page. The sex of the head determines the complicated instinctive reactions of these individuals regardless of the sex-constitution of the rest of the body. × 14.



STING AND CLASPERS

Figure 14

External genitalia of gynandromorph shown in Figure 13*C*. There is a complete set of male organs including first and second pairs of claspers and penis. Female organs are those of the left side only including the elongate sensory appendage and two elements of the sting. × 100.

by M. M. Torvik has left side (Figure 13*E*) male anteriorly with orange eye and female posteriorly with large sternites. The right side (Figure 13*D*) is female anteriorly with eye mostly black and male posteriorly. Ocelli are male and orange as is also a small patch in the anterior portion of the right eye. External genitalia are male.

The mother was orange, *o*, the father cantaloup, *c*. Male parts are therefore haploid and genetically orange, *o*, as shown in eyes and ocelli, while female parts are diploid and heterozygous, *OoCc*, showing as reconstituted black in the eyes.

Thorough tests indicated that the specimen was in general negative to caterpillars, although at one time it gave a slight positive reaction. It attempted vigorously to mate with females but was unable to do so.

A second gynandromorph (No. 335) found by M. M. Torvik came from a cross of an orange-eyed female with short wings, *o sh*, by a type male, *O, Sh*. Left antenna is female, right, male. Eyes and ocelli are all black but the right ocellus is slightly larger than the left, due either to mixed origin or to modification by adjacent male tissue. The right wings are both much shorter than the corresponding left due not only to sex difference but also to

DESCRIPTION OF GYNANDROMORPHS SHOWN IN FIGURE 13

A

A gynandromorph with male head and female abdomen and wings. The mother had the factor long, the father had the dominant allelomorph. Antennae are haploid and show the matroclinous trait; wings show the dominant character brought in by the sperm to the diploid female parts. Compare figures 11 and 12. The specimen has ivory eyes, characteristic of its parents. × 14.

B

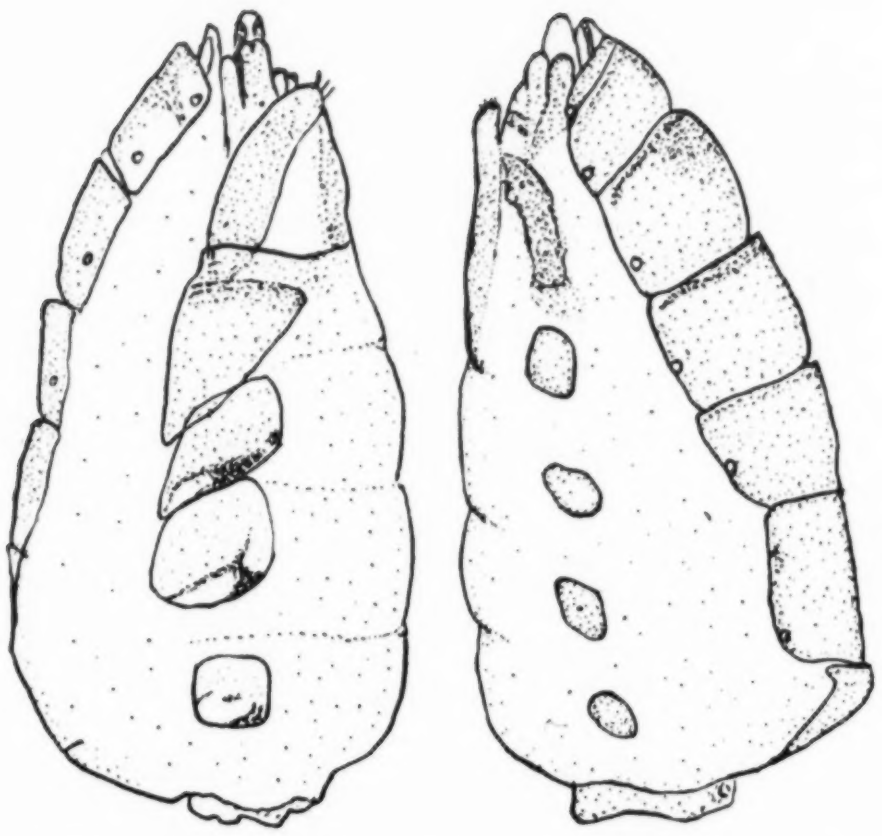
A gynandromorph with female head and predominantly male abdomen. The large abdominal sternites indicate islands of female tissue. The mother had light red eyes called cantaloup, *c;* the fatherhad orange eyes, *o*. The jet black eyes of the gynandromorph are due to the fact that the head is female, diploid, and heterozygous for both factors, *OoCc*. If this speciment had bred it might have produced cantaloup offspring, for its male tissues should be matroclinous. × 14.

C

A gynandromorph with left side female, right male. Note the shorter antenna, black eye, larger wings, more complete R_4 vein and larger abdominal sternites on the female side. The mother was orange with factor for defective R_4 vein. The father was type (black-eyed, normal veined). The female side shows the dominant paternal characters, while the male side is matroclinous. × 14.

D

This gynandromorph has the head mixed, male on the left side as may be determined by length of antenna. The orange eye and ocelli are of maternal origin. The black color of the right eye is female, a color reconstituted by combination of the dominant allelomorphs to orange and cantaloup, *OoCc*. The abdomen is opposite to the head, female on left, male on right. The instincts were male but the animal was unable to mate. × 14. *E* shows the other side of this same individual.



SEX DIFFERENCES OF TWO SIDES

Figure 15

The left, female side, and the right, male side, of a gynandromorph showing difference in sternites. × 40.

the factor *sh* received from the mother. Abdominal sternites are female on left side, male on right (Figure 15). External genitalia are normal for male.

The reproductive instincts of this insect were male like its genitalia for it attempted many times to mate with females. It was unable to do so since it always thrust its abdomen to right of female's body and far forward.

The junior author has carried on extensive breeding tests of gynandromorphs found in a series of experiments in which females homozygous for orange eyes, *o,* and for defective venation, *d,* were crossed with type males. Success was attained in only four cases which follow.

Number 395 has left antenna male, right female. Left eye is orange, right black. Ocelli are orange and male. Primary wings are of same size and each has R_4 completely lacking. Left secondary wing is much smaller and therefore male. Back of head is darker on the left (male) side. Abdomen is in general female on left side, male on right, with male genitalia (Figure 16) which are normal except for what appears to be an extra clasper on the right. Sternites (Figure 17) are small

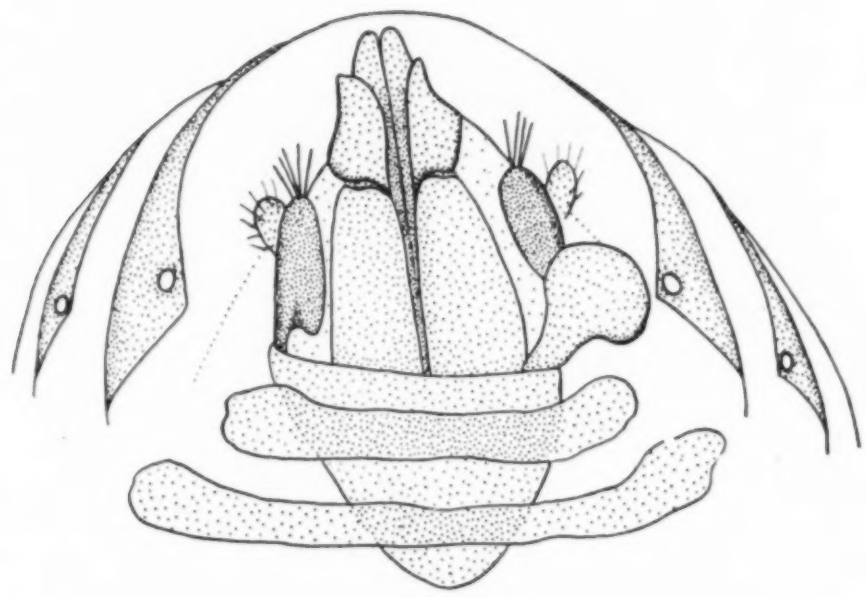
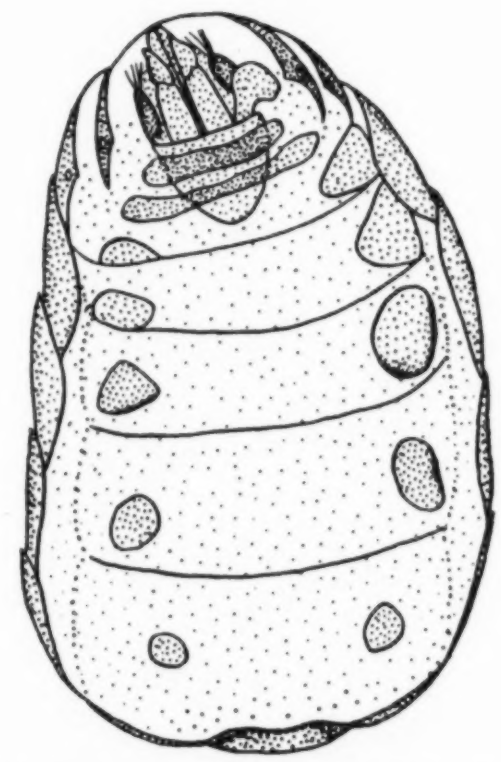


Figure 16

Male genitalia of a fertile gynandromorph. There is an extra clasper on the right side. × 100.



ANATOMICAL DETAILS OF FERTILE GYNANDROMORPH

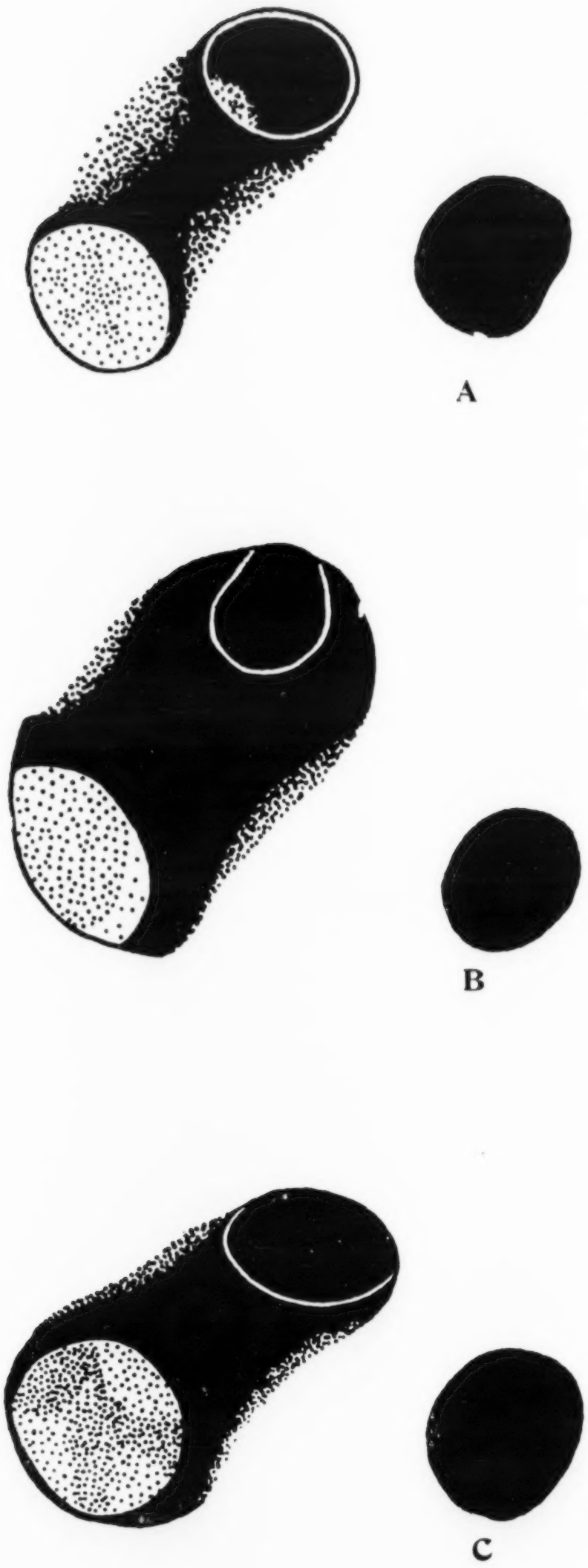
Figure 17

Ventral view of abdomen of the fertile gynandromorph shown in Figure 16. × 40.

(male) on left side, larger (female) on right.

This gynandromorph functioned normally as a male and was crossed with an ivory-eyed female. Ivory, o^i, is an allelomorph to orange, *o,* and hence the appearance of 30 orange daughters, oo^i, besides the 36 ivory, o^i, sons, indicated that testes were of maternal origin as expected. No record was taken of venation.

Number 475.5 has left antenna female, right male. Left eye is black, right is black with an orange spot ventrally. Left ocellus (Figure 18*A*) is orange and male with area about it black; median is mixed, black for the



DIFFERENCES IN EYE COLOR

Figure 18

Ocellar areas of three fertile gynandromorphs, Nos. 475.5, 448, and 503, respectively. In each case the left side is male with darker integument, but the large male ocellus of this side is lighter than the small female ocellus on the right. Male parts of eyes show the maternal orange color while female parts show the dominant paternal black. × 300.

FUSION OF SEGMENTS

Figure 19

Left male antenna of gynandromorph showing spiral fusion of segments. Irregularities of this tvpe seem rather frequent in gynandromorphs. × 100.

most part but with light spot on left side; right is black and female with area about it yellow. Wings are symmetrical with R_4 lacking from both and hence to be regarded as haploid, male, and genetically defective, *d*. Abdomen is completely male. There is no asymmetry in body pigment.

This gynandromorph also functioned normally as a male and was mated to an orange defective female. There were produced 23 orange defective daughters in addition to 23 orange defective sons. The fact that the females were defective like their brothers, shows that the gynandromorph bred as might be expected if testes were of maternal origin.

Number 448 has left antenna male, right female. Left eye is black ventrally, orange dorsally. Right eye is black with small orange spot dorsally. Left ocellus (Figure 18*B*) is orange and male; right and median are black and female. Ocellar area is blacker on left, male, side. Wings are symmetrical with normal venation and hence to be regarded as diploid, heterozygous, *Dd*, and female. Abdomen is female throughout.

This gynandromorph functioned as a female, stung caterpillars and laid eggs, producing five males with black eyes and four with orange. She therefore bred as a heterozygote *Oo*. No record was made of venation of offspring.

Number 503 has left antenna male (Figure 19) with more or less spirally fused segments, right antenna female and normal. Left eye is orange with black region anteriorly; right is black. Left ocellus (Figure 18*C*) is large with light brown pigment, probably male and orange genetically, or mixed; median and right are black and female. Area between median and left is black (male), between median and right yellow (female). Left wings are smaller than right and therefore probably male. Left primary wing has R_4 missing; right primary has R_4 with a slight break. Abdomen is entirely female.

This gynandromorph functioned as a female, stung caterpillars and laid eggs from which developed males: type 1, defective 1, orange 1, and orange defective 2, and females: type 3, defective 4, orange 4, and orange defective 5. The gonads were diheterozygous, *OoDd*, as expected. The gynandromorph had mated with one of its orange defective brothers.

Summary

Despite the fact that reproductive instincts of gynandromorphs are usually opposite to the sex of the gonads, there have been found six in which there was agreement. Two of these with male instincts and genitalia were unable to mate, two functioned as males, and two as females.

Origin of male parts of gynandromorphs has hitherto been assumed to be maternal on the basis of visible recessive traits only. Breeding tests from the two specimens functioning as male shows that male gonads are of maternal origin.

Female parts of gynandromorphs have hitherto been assumed to be biparental, because dominant traits possessed by either or both parents appeared in these parts. Breeding tests from the two specimens functioning as female show that ovaries are actually heterozygous transmitting recessive maternal traits as well as dominant factors received from their fathers.*

*Work reported in this paper has been aided in part by a grant from the National Research Council, Committee on Effects of Radiation on Living Organisms. The project outlined under the grant is "Genetic Study of the Parasitic Wasp, Habrobracon, with the Purpose of Throwing Further Light on Such Problems as Sex-Determination, Parthenogenesis, and Gynandromorphism."

HEREDITARY VARIATION OF THE CHINCHILLA RABBIT

In Coat and Eye Color

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IT is well known that the coat of certain fur bearing mammals has a tendency to fade. Especially is this found among animals in which black is the predominating pigment of the coat. This characteristic has been variously attributed to diet, environment and breeding and it is not improbable that each may have its effect under certain circumstances. Recent experiments have brought to light some interesting facts regarding the color phases of the chinchilla rabbit and their inheritance which may be of interest to rabbit breeders and perhaps to breeders of other fur-bearing animals in so far as they bear upon the general problem of permanency of coat color.

Chinchilla coat color has been found in mice and in guinea pigs as well as in rabbits and it is not improbable that it may be found among many other animals. As compared with the ordinary gray type, it is characterized primarily by absence of yellow pigment from the coat, while black is either undiminished or but slightly reduced. It is inherited as an allelomorph of full color and of albinism.

In order to explain briefly the meaning of this last statement I should like to call attention to the fact that according to the modern conception of Mendelian heredity, all inherited characters depend for their production upon genes (genetic factors) which are transmitted from generation to generation in the nucleus of the reproductive cells. Union of the ovum or female gamete or reproductive cell with the sperm or male gamete results in a duplication of these genes in the fertilized egg which is to produce the new individual. Every cell which thereafter results by division and growth of this fertilized egg normally contains all of the genes in this paired condition, until the maturation of the reproductive cells occurs (forming eggs or sperm) at which time each of these pairs is again separated.

The genes have been proven each to occupy a definite position in one of the deep staining bodies called chromosomes, which are visible parts of the cell nucleus, to be seen under high magnification at certain stages in cell division. In rabbits, the number of these pairs of chromosomes has been found to be 22. The members of each pair of chromosomes are visibly alike and are homologs but they differ in size and shape from each of the other twenty-one pairs. Genes which occupy identical loci or spots of homologous chromosomes are known as allelomorphs. In the normal wild type rabbit each gene is like its mate (allelomorph) and little or no variation is found in the stock from generation to generation. Occasionally, however, the internal structure of some one gene becomes altered, the cause of which may as yet be only speculated upon, and a new variation, mutant or sport, as such products have been variously termed, results.

Allelomorphs of Albinism

Sometimes a gene will be found to have mutated several times producing each time a different mutant type. Since they are but alterations of the same gene they occupy the same loci of homologous chromosomes and behave as allelomorphs in inheritance. Since never more than two chromosomes of any one kind are normally

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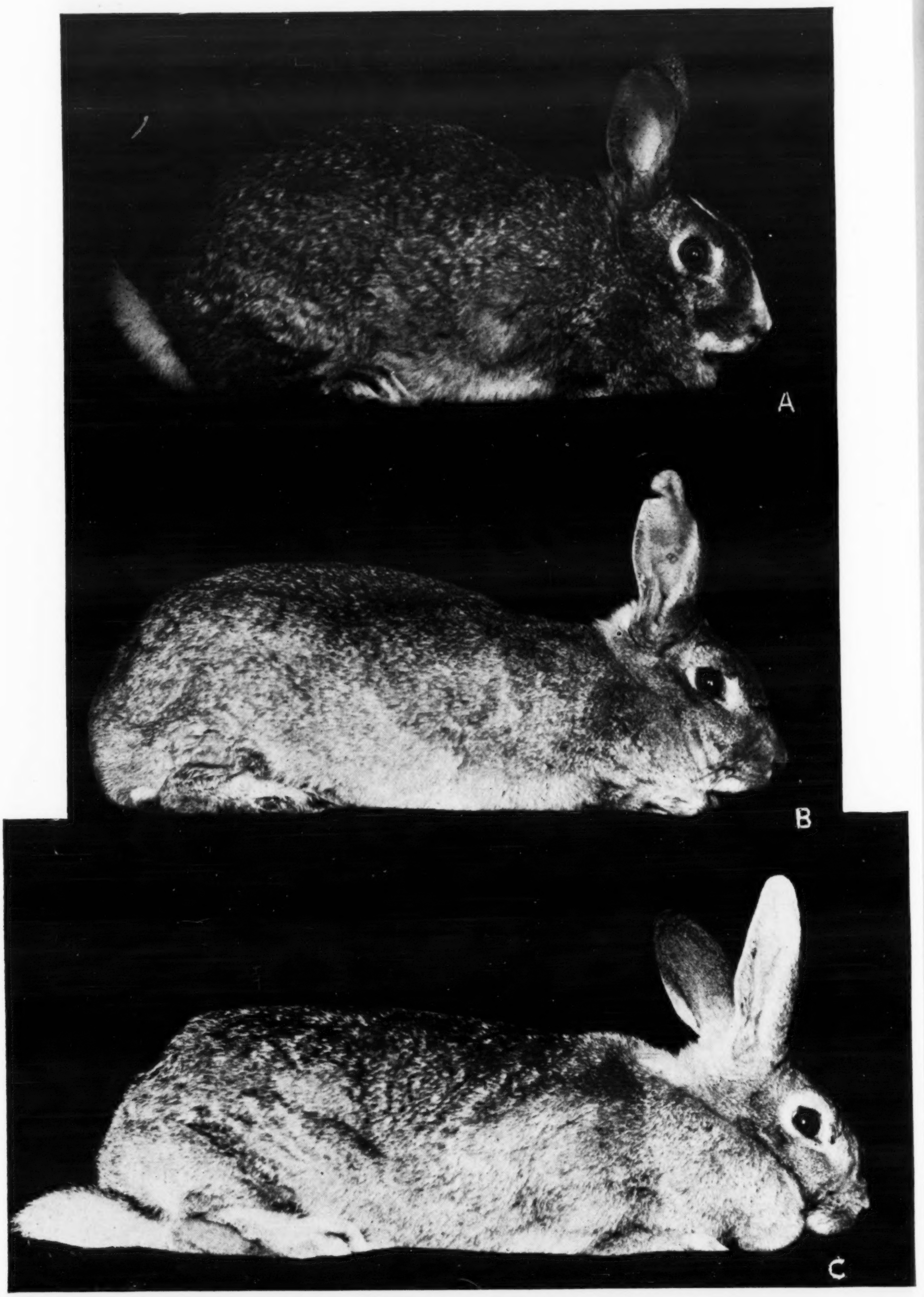


CHINCHILLA COMBINATIONS

Figure 20

A—Blue-eyed dark chinchilla (ch^3); *B*—Pale chinchilla (ch^1). Note the less intense black pigment which is especially evident on the sides; also the brown eyes as compared with *A*; *C*—Dark chinchilla (ch^3) with gray (modified blue) eye.

found in any one individual it is never possible to combine more than two of these mutant types in any one individual.

One of the most common of such mutants which occurs in the wild is albinism. Two different albino mutants are known among mammals. One of these has been designated the complete albino since it appears to be incapable of developing any pigment whatever. The hair, skin and iris of the eye are white and the pupil of the eye is pink or red. The second type is exemplified in the Himalayan race of rabbits in which the extremities (ears, nose, feet and tail) develop some pigment. The albino guinea pig is of this type.

Associated with the Himalayan gene is the interesting phenomenon of temperature sensitivity of the pigment producing mechanism. It is a well known fact among those who have had experience with the Himalayan rabbit that the young are born as devoid of pigment as are the young of their true albino cousins. With the moult of the juvenile pelage appear the characteristic markings of the race. Schultz[1], a German investigator, and others, found that the plucking of the fur from spots on the back of these rabbits during seasons of low temperature resulted in the production of new fur upon these areas which was pigmented. This indicated that the slightly reduced temperature of the spots from which the fur had been plucked was responsible for pigment production and that the normal markings of the extremities were also due to a slightly reduced temperature of those regions of the body. By proper manipulation of eye tissues Schultz has since been able to demonstrate that they also are capable of producing pigment outside of the body at reduced temperatures.[2] The newborn Himalayan is non-pigmented because the tips of the hairs, already developed at birth, have been formed within the body of the mother at a temperature too high for pigment production. But hair grown after birth becomes pigmented in those regions of the body where the temperature is sufficiently low.

Allelomorphs of Chinchilla

In the ordinary wild type rabbit which is a gray or agouti like that of the Gray Flemish, both black and yellow are found to be well developed. For this the color gene (C), commonly referred to as full color, is responsible. Complete albinism (c) may be considered as due to an alteration in the internal structure of the full color gene (C) such that at normal temperatures it is incapable of pigment production. The Himalayan gene (c^H) is a similar alteration which is incapable of pigment production at the usual body temperature but may produce it at average atmospheric temperatures which the skin of the extremities of the animal approaches.

If the (C) gene and its variants (c) and (c^H) are carried only in pairs as indicated above, it follows that a single individual may never carry more than two of these variations. The possible combinations are CC, Cc^H, Cc, c^Hc^H, c^Hc, and cc. Crosses readily demonstrate the fact that full color (C) is completely dominant to Himalayan (c^H) and also to (c). One dose of (C) is equivalent to two in so far as the general appearance of the animal is concerned. Known CC ,Cc^H, and Cc types are indistinguishable from each other. Himalayan albinism (c^H) is also found to be dominant to true albinism but as indicated above is recessive to full color. This relationship which is known as allelomorphism was known as early as 1906. Castle[3] who was the first to record it, was also the first to point out that the chinchilla rabbit which was discovered during the World War behaves as an allelomorph of albinism and full color and therefore is due to still another modification of the full-color gene.[4]

Since that time two other types of chinchilla have been recognized,[5, 6, 7] making a total of six allelomorphs in this series. Arranged in the order of

BLUE-EYED DARK CHINCHILLA[3] IN COMBINATION WITH NON-AGOUTI (*aach³ch³*)

Figure 21

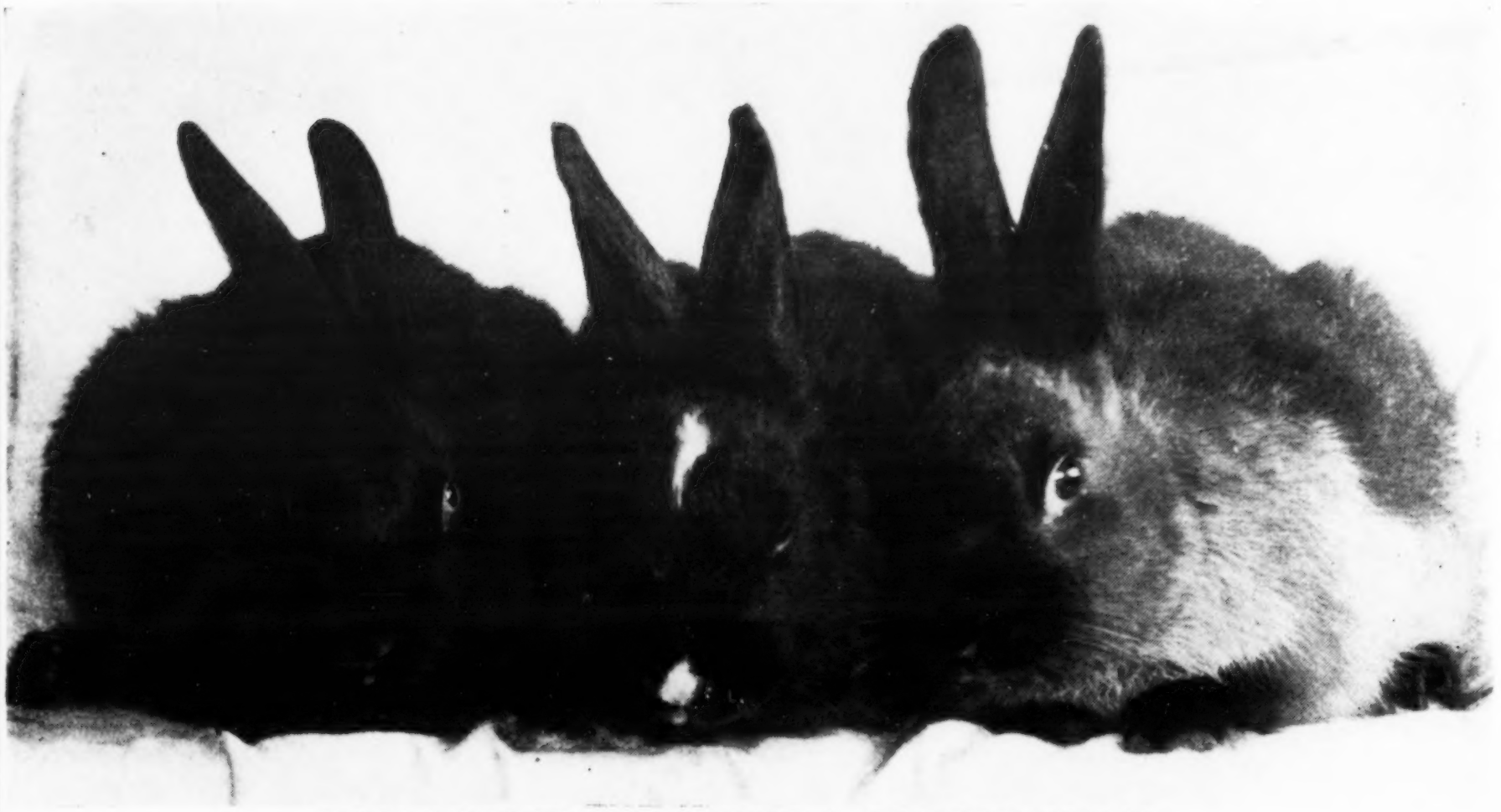
Note the intense black pigmentation of the fur. The white hairs are a form of silvering due to hereditary factors apart from chinchilla or agouti.

dominance, they are full color (*C*)* dark chinchilla (*ch*³), light chinchilla (*ch*²), pale chinchilla (*ch*¹), Himalayan albinism (c^H) and true albinism (*c*). The possible combinations including the six homozygous or true breeding types total twenty-one and the possible chinchilla types alone total twelve.

Pale chinchilla (*ch*¹) (Fig. 20*B*), develops the least pigment of the three chinchilla types and is characterized not only by its brownish black pigment but also by being lighter on the sides and belly, while the extremities, especially in cold weather and in the new coat, are darker than the rest of the body, as in the Himalayan. It is only partially dominant to the two albino forms, the hybrid or heterozygous combinations *ch*¹*c* and *ch*¹c^H being much lighter in color than the homozygous *ch*¹*ch*¹ true breeding type, especially as regards the color of the sides. The agouti combination (*AAch*¹*ch*¹) is the undesirable brown-sided chinchilla while the non-agouti combination (*aach*¹*ch*¹) is the Sable, most prized by the fancier in the heterozygous combination with albinism (*aach*¹*c*) although it will not breed true, since it produces both the homozygous dark type and the albino as wasters. (See Figure 22.)

Light chinchilla (*ch*²) develops a greater amount of pigment than pale chinchilla (*ch*¹), when either heterozygous for albinism or in the homozygous condition. In combination with albinism both non-agouti (*aach*²*c*) and agouti (*AAch*²*c*) are almost indistinguishable from respectively similar types of true breeding sable (*aach*¹*ch*¹) and pale chinchilla (*AAch*¹*ch*¹). The only difference between ch² and ch¹ types is found in the uniformity of the former in contrast to pale chinchilla types which are lighter in color on the sides. (See Figure 22.) The combinations of pale with light chinchilla, either agouti (*AAch*²*ch*¹) or non-agouti

*The reader will find the symbols here used similar to those of Castle, W. E., "The Genetics of Domestic Rabbits," Harvard University Press, Cambridge, Mass. As there are now three chinchilla types numbered 1, 2 and 3 or according to Castle's terminology c^{ch1}, c^{ch2}, and c^{ch3} for simplicity I have designated them merely (ch¹), (ch²) and (ch³).



NON-AGOUTI-CHINCHILLA COMBINATIONS

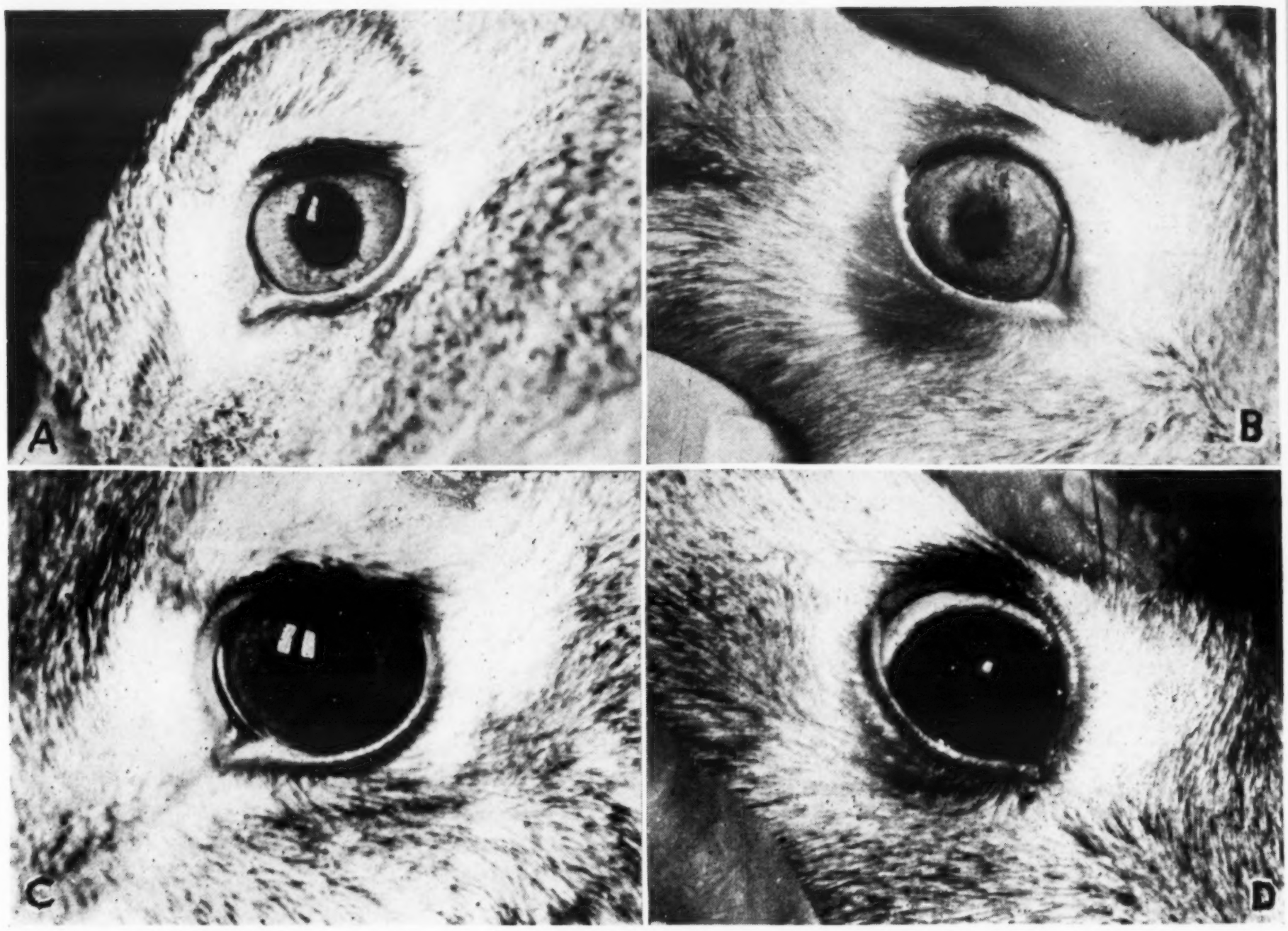
Figure 22

Three-months-old individuals in which non-agouti is combined with each of the three types of chinchilla. Note the different intensity of pigment in the coat of each. The individual at the left is dark chinchilla. In the center is light chinchilla and at the right is pale chinchilla or sable. Each of these carries albinism.

($aach^2ch^1$), are perceptibly darker than the homozygous pale (ch^1ch^1).

Dark chinchilla (ch^3, Fig. 20*A*) is the type which in the agouti combination appears to be necessary for the production of the non-fading dark coat of the fancier's preferred type of chinchilla. Unfortunately the characters blue and gray eyes considered by fanciers as undesirable are closely associated with if not a part of this allelomorph. Blue-eyed dark chinchilla is completely dominant to the albino forms, the heterozygous (ch^3c) or (ch^3c^H) being indistinguishable from the homozygous (ch^3ch^3) individual or true breeding blue-eyed dark chinchilla. In combinations of dark chinchilla with either light chinchilla (ch^3ch^2) or pale chinchilla (ch^3ch^1) the eye however becomes brown. Dark chinchilla produces the desired coat color but light or pale chinchilla is necessary for the desired brown eye color. The mating of such heterozygous individuals together, however, results in 50% wasters since one-fourth of the offspring are blue-eyed dark chinchillas and one-fourth are light or pale chinchillas as the case may be. Under such conditions the most economical procedure is the maintenance of both true breeding strains, of dark chinchilla which is blue-eyed and light or pale chinchilla which is brown-eyed, and the crossing of these two for the production of show animals or market pelts. Such a cross produces 100% of the desired type. The non-agouti dark chinchilla ($aach^3ch^3$) is black and is indistinguishable except by eye color from any other black rabbit. (See Fig. 21).

Genetical analysis of the dark chinchilla has shown that the blue eye is also affected by genes known as modifiers because of their secondary influence upon the principal factor blue-eye. Evidence has been obtained that these are at least several in number. In their absence (or recessive condition) an eye is produced of very nearly as clear a blue as that found in the Vienna White rabbit, but the cumulative effect of several active (or dominant) modifying genes produces an increase of pigment in the front wall of the iris resulting in various degrees of gray or mottled eye (see Figures 20, 21 and 23). A maxi-



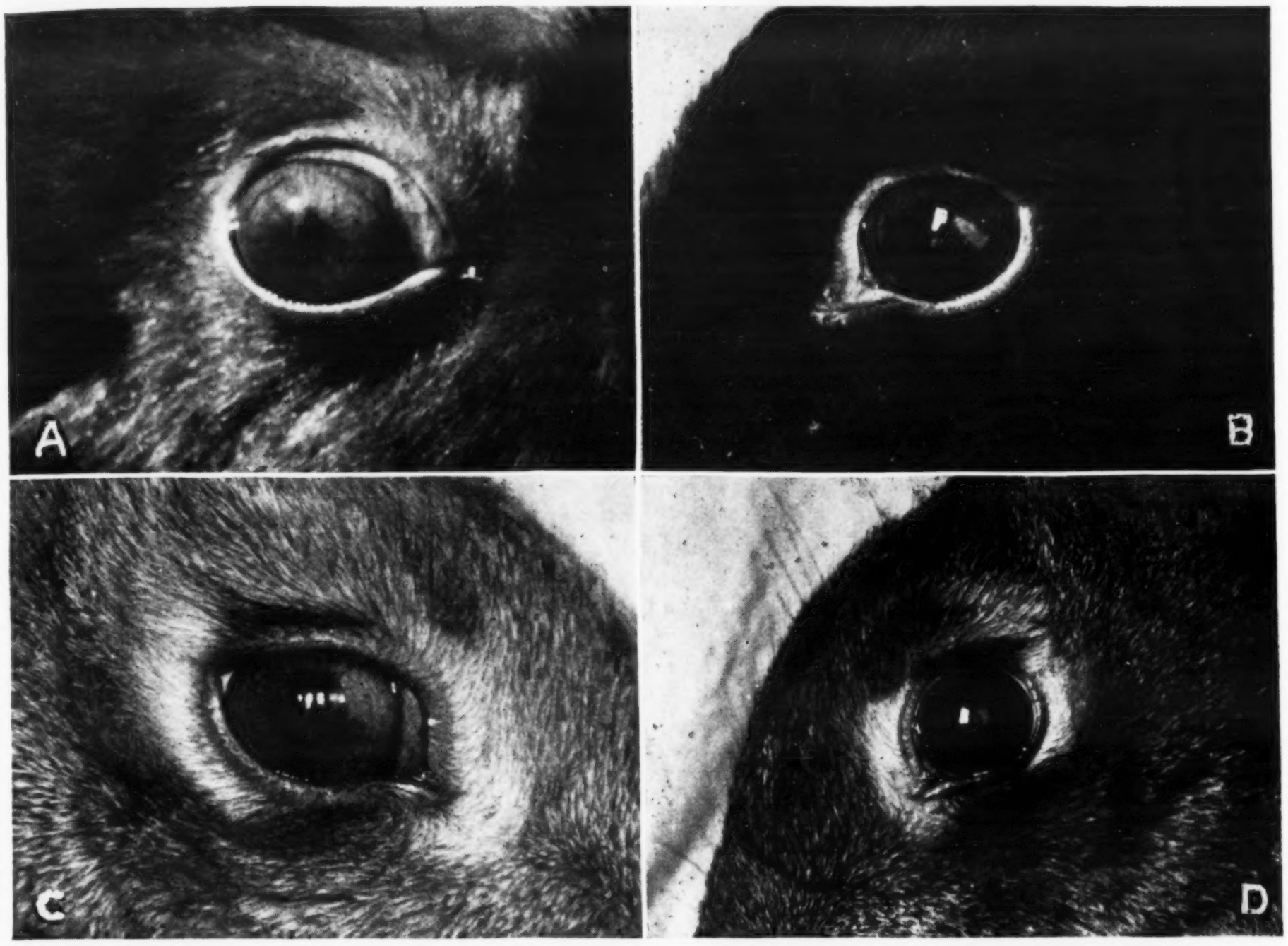
VARIATION OF EYE-COLOR IN DARK CHINCHILLA RABBITS

Figure 23

A—Typical blue eye with a minimum of pigment on the anterior wall of the iris. *B* and *C*—Gray eyes, also genetically blue but with intermediate amounts of modification. *D*—Pseudo-brown eye, genetically a blue but with a maximum of genetic modifiers producing anterior iris pigmentation.

mum condition is reached in a pseudo-brown (Figure 23*D*), which has been observed to be more intensely brown than many of the brown-eyed dark chinchilla (ch^3ch^2) or (ch^3ch^1) heterzygotes. Pseudo-brown eyed individuals may probably be true-breeding but up to this time they have not been sufficiently investigated. Gray-eyed types characterized by minute blue-spots in the iris which brown pigment has failed to cover may produce offspring with blue, gray or pseudo-brown eyes. Gray and pseudo-brown eyes are always very bluish at weaning age and become darker as the animal grows older.

Two genetic agencies then are involved in producing the eye color of the chinchilla. One (blue eye) is closely associated with dark chinchilla. Its allelomorph (brown eye) is associated only with full color, light chinchilla or pale chinchilla. If this were the only agency involved, brown-eyed dark chinchillas would never be found to be true breeding. The second agency is a group of modifying genes which influence the pigmentation of the front surface of the iris. These make possible a true-breeding type. They are independent of the albino series since corresponding variations in the intensity of pigmentation of the iris (varying shades of brown) have been found among the full color, light and pale chinchilla segregates, as well as varying shades of blue, gray and pseudo-brown among dark chinchilla segregates from crosses designed to test the inheritance of this particular character. The eyes of full colored, light and pale chinchillas which lack these modifying genes are bluish at weaning age but by the time sexual



VARIATION OF EYE-COLOR IN LIGHT CHINCHILLA (ch^2) AND IN FULL COLORED RABBITS.

Figure 24

A—Light brown eye of light chinchilla without modifiers. Compare with Fig. 23*A*. *B*—Dark brown eye of light chinchilla containing modifiers. Compare Fig. 23*D*. *C*—Light brown eye of full colored rabbit lacking modifiers. Compare Figs. 23*A* and 24*A*. *D*—Dark brown eye of full colored rabbit containing modifiers. Compare Figs. 23*D* and 24*B*.

maturity is attained they are a very light brown in color (Figures 24*A* and 24*C*). The maximum effect of these iris modifiers in full colored or in any of the three chinchilla types is the production of an intense brown-black iris (Figure 24 *B* and *D*).

Production of Brown-eyed Chinchillas

From the above facts it is obvious that two methods of producing brown-eyed chinchilla rabbits are possible. The first and most certain as already indicated is to cross light or pale chinchillas (which are brown-eyed) with blue-eyed dark chinchillas, which contribute the desired coat color. Brown-eyed dark chinchillas produced by this method are, however, not true breeding.

The second method is the selection for a number of generations of only the darkest gray-eyed chinchillas for breeding, preferably those of the pseudo-brown type. Obviously if a true-breeding race can be established by this method it is more desirable than a type not true-breeding. The nature of these two genetic complexes is such that the two methods may be readily combined, so that while practising the first method the breeder may also by selection of chinchillas with the darkest eyes (either brown or gray) build up in a few generations the desired race breeding true for eye color. After this has been secured, the pale or light chinchilla waster classes may be permanently eliminated by back-cross breeding tests which will identify the desired homozygous brown-eyed dark chinchil-

las, those which will breed true for the desired characters of both coat and eye color.

Conscientious breeders undoubtedly have indirectly been practising this combination method by mere selection of the darkest eyed chinchillas. This attains the same end but may produce more wasters during the process.

Two facts are of value to those interested in the promulgation of breed standards. First, there appears to be no good reason for adopting the brown eye other than personal preference based upon aesthetic appeal. From the genetic standpoint it appears much easier to obtain a condition of true breeding to the desired coat color in the blue-eyed chinchilla. But secondly, if brown eye is to be given preference, the genetic evidence is that the most intensely pigmented brown-eyed individual is most likely to breed true.

The pigment of light and pale chinchillas is subject to temperature influences much as is that of the Himalayan rabbit and the Siamese cat. This is most pronounced in the Sable or non-agouti pale chinchilla which has been studied in some detail by Kosswig. In this rabbit the extremities are always dark as in the Himalayan. At birth both pale and light chinchillas (and their non-agouti combinations) are a uniform color over the entire body but a little later the tips of the guard hairs which had developed in the warmer temperature of the mother's body before birth will be found to be lighter in color than the parts formed after birth. If the animal is born at a cold season of the year the contrast between these light tipped guard hairs and a very dark under fur developed in the cold, is such as to give the animal a frosted appearance. Dark chinchilla thus far has given no indication of being affected by temperature differences.

Pale and light chinchilla are also extremely subject to fading. The new fur always develops a much darker color in contrast to the old pelage which has faded. Dark chinchilla also fades but to such a slight degree that it requires close examination under good light to detect the difference between old and new fur in a moulting non-agouti or black animal and in the agouti combination which is the normal dark chinchilla it is still more difficult.

The cause of fading I believe is not clearly understood. Sunlight, lack of humidity and other environmental influences are under suspicion. Breeding has also come in for its share of blame. In the three chinchilla allelomorphs in the rabbit we have a clear cut example of hereditary color factors which exercise an influence on ability to withstand whatever environmental influences are responsible for the fading phenomenon. This indicates that breeders of fur bearing animals whose stock has a tendency to fade might profitably give some thought to the breeding of their animals in this respect.

Details of the breeding experiments here described which have been carried on at the Bussey Institution of Harvard University, Boston, Mass., are to be published elsewhere.

Literature Cited

1. Schultz, Walther, 1918. Versteckte Erbfactoren der Albino für Farbung beim Russenkaninchen im Soma dargestellt und rein Somatische zur Wirkung gebrocht. *Zeit. f, indukt. Abstamm. u. Vererbungslehre* 20:27-40.

2. ———————, 1930. Luft melaninbildung bei Zimmer Temperature in Saugetier Augen and Haarwurzeln. *Arch. f. Ent. w. mechan.* 123:132-152.

3. Castle, W. E., 1905. Heredity of coat characters in guinea pigs ond rabbits. *Carnegie Inst. Washington Publ.*, no. 23. p.78.

4. ———————, 1921. Genetics of the chinchilla rabbit. *Science n. s.* 53:387-388.

5. ———————, 1926. Studies of color inheritance and of linkage in rabbits. Part I. *Carnegie Inst. Washington Publ.*, no. 337, pp. 1-9.

6. Kosswig, C., 1927. Uber die Vererbung and Bildung von Pigment bei Kaninchenrassen. *Zeit. f. indukt. Abstamm. -u. Vererbungslehre* 45:368-401.

7. Nachtsheim, E., 1929. Die Entstehung der Kaninchenrassen in Licht ihrer Genetik. *Zeit. f. Tierzüchtung usd Zuchtungsbiol* 14:53-109.